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Carbon Sequestration as a Function of Intercropping Management Practice and Different Nitrogenous Fertilizer Types

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ABSTRACT

This study has been carried out through an experiment conducted at El-Giza Agricultural Research Station to examine the short-term effects (3 years) of two cropping patterns-based on intercropping system and N fertilization on quantifying of crop& soil carbon sequestration and soil carbon dioxide emissions targeting to test the ability of this management to mitigate global warming which produced from increased concentration of atmospheric CO_2which would essentially reflect upon climate change mitigation .Also, the impact of soil temperature and moisture changes as factors affected such emissions have put into consideration. The first intercropping pattern has been sunflower/cowpea (*Helianthusannuus, va.Sakha, 53/Vigna unguiculata. local*).Second intercropping pattern has been wheat/peas (*Triticum aestivum L* va, Sakha 94/*Pisum sativum L*va, Master b.).The first intercropping pattern has been arranged in 2:2,2:3 rows of sunflower: cowpea, sole sunflower and sole cowpea (4 configurations) while the 3: 2,5:2 rows of wheat: peas , sole peas and sole wheat (4 configurations) have been done for the second pattern. The N-fertilizers have been urea and ureaform (slow release nitrogen fertilizer); in rate of 60kg N fed^{-1}for sunflower/cowpea intercrop,110 kg N fed^{-1} for wheat/peas intercrop, 30 kg N fed^{-1}forsole sunflower and 30 kg N fed^{-1}for sole cowpea from urea added for every season.100kg N fed^{-1} for sunflower/cowpea intercrop,50kgN fed^{-1} for sole sunflower and 50kgN fed^{-1} for sole cowpea from ureaform added for every two seasons. Wheat/peas intercrop; sole wheat and sole peas (in second season) have not been taken N-fertilizer but grown on the residual ureaform-N. Soil CO_2 emissions have been weekly measured from October 3rd, 2010 to May 9th, 2013, us ingstatic chamber technique. Such emissions have been absorbed through NaOH followed by HCl titration. Also, soil temperature and moisture have been weekly recorded. Soil sampling after harvest has been taken to determine some physical and chemical properties. After three years of practicing this management, the results indicate that, under the conditions of this experiment, soil temperature varied between 12and 45Cº at 5 cm depth, soil moisture varied between 2 and 55% at the same depth. Statistically, they have shown no or poor correlations with soil emitted-CO_2.The quantities of soil-CO_2 emitted from irrigated plot treatments and determined in summer seasons have been higher than those of non-irrigated ones and those determined in winter seasons. Intercrops patterns and UF fertilizer have been contributed to obtain a lower emitted CO_2 quantities from soil compared to sole crops patterns and urea fertilizer. The obtained yield from intercrops patterns treatments and UF fertilizer have been higher than those of sole crops patterns ones and urea fertilizer. Intercrops patterns and UF fertilizer have been found to be efficient in increasing sequestered carbon either in crop biomass or in soil; the crop sequestered-C relative increase for intercrops to sole crops values have seasonally varied between 42.06 and 77.75% for sunflower /cowpea intercrops and between -12.01 and 0.46% for wheat/peas ones. The crop sequestered-C relative increase for UF to urea values have varied between 6.78 and 10.51%under sunflower/cowpea intercrops and between14.60 and30.05 % under wheat/ peas ones. ..Regarding soil sequestered carbon over 3 years ,sequestered-C relative increase for intercrops to sole crops has amounted 5.83% and for UF to urea amounted 47.08%.The marked gradual improvement in soil organic matter content, EC, pH, BD, available-N, stable aggregates% and porosity have positively reflected on changes in the soil sequestered carbon quantities.

Keywords: ureaform; slow release fertilizer; urea; intercrops; sole crop; emitted CO_2; sequestered-carbon.

INTRODUCTION

To mitigate global warming, carbon sequestration strategy (The process of removing carbon from the atmosphere and depositing it in a reservoir) may be the reliable key to achieve it. Soil is an ideal reservoir for storage of organic carbon (OC) (Flach *et al.*, 1997; Paustian *et al.*, 1997a, 1997b; Lal *et al*, 1998; Bruce *et al.*,1999; Sperow *et al.*, 2003). The soil C pool naturally comprises soil organic C estimated at 1550 Pg (1 peta gram =10^{15} g = 1 billion ton) and soil inorganic C approximates 750 Pg both to 1 m depth. This total soil C pool of 2300 Pg is three times the atmospheric pool of 770 Pg and 3.8 times the vegetation pool of 610 Pg (Batjes, 1996). Then soil organic C pool has a great potential to store sequestered C. However soil organic C was usually prone to depleting due to land misuse and inappropriate management for the long history (Qingren Wang *et al.*, 2010).In this respect, Intergovernmental Panel on Climate Change (1995) documented estimates that globally agriculture emits about 20% of all emitted-carbon dioxide. Alvarez *et al.*(1998) reported that increased agricultural intensification and the adoption of sole crop production systems in the Argentine Pampa during the past 40 years reduced levels of soil organic matter up to 50%.Lal (2000)stated that most croplands lost 30-40 Mg C ha^{-1} and most degraded soils lost 40-60 Mg C ha^{-1}.Lal(2001)calculated a reduction in soil C pool by 1 Pg is equivalent to an atmospheric enrichment of CO_2 by 0.47 ppm. On the other hand, Tans *et al.*,(1990) calculated the potentiality for increasing C as CO_2 storage into soils and found that it equals 1.3 – 2.4 10^9 metric tons of carbon year^{-1}. Lal (2004) determined that much of the historic C loss (about 66-90 Pg C) from the soil can be restored via C sequestration in 25-50 years with appropriate land management. Soil C sequestration studies in the crop land of major countries showed that the cropland can sequester about 75-208 Tg C yr^{-1} in US, 24 Tg C yr^{-1} in Canada, 90-120 Tg C yr^{-1} in the European Union, 105-198 Tg C yr^{-1} in China and 39-49 Tg C yr^{-1} in India (1 Tera gram= 10^{12} g) (Hutchinson *et al.*, 2007). Smith and Falloon(2005) reported that the potentiality for carbon storage in European cropland is about 90-120 Tg Cyear^{-1}. Estimation of C sequestration potential on crop land under corn in the Piketon County, Ohio, USA was 8.53 ± 0.2 Mg ha^{-1}(Adhikari*et al.*, 2013).

To optimize the efficiency of C sequestration in agriculture sector, cropping systems such as crop rotation, intercropping, cover cropping, etc., play a critical role by influencing optimal yield, total increased C sequestered with biomass and that remained in the soil (Kimble*etal.*1998; Qingren Wang *et al.*, 2010; Smith *et al.*, 2000; West and Post, 2002 and Lal, 2004).
Intercropping system is one of the most powerful tools to pull carbon from the atmosphere and sequester it in the soil for long-term storage because it is able to utilize sunlight with an adequate spatial distribution of various plant architectures and produce greater biomass either above or below-ground per unit area than single crops as a result of complementarities in resource use and facilitation between component crops (Kong *et al.*,2005).Intercropping means growing of two or more crops simultaneously on the same area of land with a definite row pattern and is predominant in the regions of dry, humid and semi-arid tropics(Sharma and Behera, 2009).Currently, it is also recognized in temperate areas (Hauggaard- Nielsen*et al.*,2001).Although little is known about C sequestered in intercropping practices, recently some studies conformed it. Mungai and

Motavalli (2006) observed that legume-based inter cropping systems significantly increased the retention of C in the soil. Makumba (2007) found that sequestered C in gliricidia-maize intercropping system varied between123 and149 Mg C ha^{-1} and was 1.6 times more than in sole-maize. Fang *et al*.(2010) stated that sequestered C reached 16.7 ton C ha^{-1} for the poplar-wheat–soybean intercropping system and 18.9 ton C ha^{-1} for the poplar wheat–corn one.

Soil Sequestration is a complex process that is influenced by many factors, such as soil temperature & moisture and nitrogen fertilization. As regard temperature effect, Kirschbaum(1995)pointed out that the potential increase in CO_2 release from the soil caused by future elevated temperature may have a positive feedback effect on the atmospheric CO_2 and global change. Besides temperature and moisture effects on soil or ecosystem respiration (soil CO_2 emissions) are acted simultaneously; Fang and Moncrieff (2001); Xu and Qi (2001); Reichstein *et al*., (2002); Qi *et al*.,(2002); Janssens and Pilegaard (2003) reviewed, described and revealed that the dependence of soil respiration rate may be varied as the variation in moisture and temperature changes and the interaction extent between each other.

As for nitrogen fertilization, Wang and Bakken (1997) found that the addition of mineral N-fertilizer might not only increase plant biomass production but also microbial biomass and microbial activity. The latter effect could enhance the decay of soil organic matter. FAO (2004)point out to some studies in Argentina, India, Kenya and Nigeria which illustrated that inorganic fertilizer used alone to increase nutrient supply for crops results in declines in soil C in all systems.This hypothesis has recently been supported by the study of Khan *et al*.,(2007) who showed that high mineral fertilization (NPK) led to significant losses of soil organic carbon during 51years of continuous maize cropping at the Morrow plots (Illinois, USA).

The applied nitrogen fertilizers in this study are urea as soluble form and ureaform (UF) as slow release fertilizer. The first one is a known fertilizer with several problems; N-volatilization, N-leaching, N-pollution and low fertilization efficiency. The second one is a condensed urea molecules product as a result of reaction between urea and formaldehyde consisting of short chains from methylene-di urea to tetra methylene-penta urea and synthesized by Abbady *et al*.,(1992).Alexander and Helm (2007) reviewed several trial results with UF products showing the beneficial effects of the particular kind of slow release nitrogen fertilizer in meeting needs for improved fertility management and reduced N-pollution for agro-ecosystem. Abbady *et al*.,(1997), Hegazy *et al*.,(1998) , Abbady *et al*.,(2003),Abbady *et al*.,(2008) and Abd El-Aal *et al*.,(2008)reported that application of UF led to increase yield with 10-30%.

Because of enhancing energy consumption efficiency is a one of the tools used to sequester or lower CO_2 emissions to atmosphere, more recent studies of Abbady *et al*.,(2011)and Abbady *et al*.,(2013) paid attention to the importance of UF as slow release N-fertilizer application in enhancing such efficiency and lowering CO_2 emissions produced indirectly from using urea or other conventional N-fertilizers.

The objective of this study is to determine the effect of intercropping system practice and N fertilization on crop productivity, soil &crop carbon sequestration and soil CO_2 emissions.

MATERIALS AND METHODS

The experiment has been conducted at EL-Giza Agricultural Research Station .The soil of study site has been classified as *Typic Haplotorrerts, fine, hyperthermic*, according to USDA, 2006.Some chemical and physical properties have been recorded in Table (1).The experiment has been initiated during the summer season of three consecutive years (2010–2013) with sunflower/cowpea (*Helianthus annuus L.va.Sakha,53 /Vigna unguiculata L.va.local*) intercrops as summer pattern which has been followed by wheat/peas (*Triticum aestivum L va, Sakha 94 /Pisumsativum L.va,Masterb*) intercrops as winter pattern. Those two patterns have alternatively frequented for three consecutive years to study the impact of such intercropping practice and N fertilization on soil CO_2 emissions, soil and crop carbon sequestration , soil properties and crop productivity targeting to contribute in mitigating the atmospheric CO_2 level reaching mitigate climate change.

The experiment has been consisted of 8treatments arranging with three replications in split plot design:(a) the treatments of main plots have represented the four configurations of sunflower/ cowpea intercrops as summer crops and four configurations of wheat/peas intercrops as winter crops. In addition, tow plot treatments, one of them has been leaved in dry case and the other has been irrigated as same in the experiment irrigation to determine the soil emitted-CO_2 in these cases.

The treatments(configurations)for sunflower/cowpea inter crops have come as follows:

1- 2 : 2 rows sunflower /cowpea
2- 2 :3 rows sunflower /cowpea
3- 0.0: 4 rows sunflower /cowpea (sole cowpea)
4- 2:0.0 rows sunflower /cowpea (sole sunflower)

The treatments (configurations) for wheat/peas intercrops have come as follows:

1-3: 2 rows wheat /peas
2- 5:2 rows wheat /peas
3- 0.0 :2 rows wheat /peas (sole peas)
4-6: 0.0 rows wheat /peas (sole wheat)

The summer and winter intercrops patterns have been alternatively planted in the same plots for consecutive 3 years.(b) the treatments of sub-plots have represented the two types of N fertilizers; urea as an ordinary fertilizer(46.5N) and ureaform (40%N)as a slow release fertilizer. The rate of 60 kg Nfed^{-1} for sunflower/cowpea intercrops ,110 kg Nfed^{-1}forwheat/peas intercrops,30 kg Nfed^{-1}for sole sunflower, 30 kg Nfed^{-1} for sole cowpea,40 kg Nfed^{-1} for sole peas and70 kg Nfed^{-1} for sole wheat taken from urea which have been added for every growth season.100kg Nfed^{-1} for first pattern , 50 kg Nfed^{-1} for sole sunflower and 50kg Nfed^{-1} for sole cowpea taken from UF and added for every 2 growth seasons .Wheat/peas intercrop, sole wheat and sole peas jn second season have not been taken N-fertilizer but grown on the residual ureaform-N. The experimental work has been managed adopting the permanent raised bed planting with reduced tillage (only hand weeding) in order to minimize disturbance of soil particles For sunflower /cowpea intercrops pattern; sunflower has been planted on all sides of120 cm wide and 20 cm high beds with planting one plant hill^{-1} , 25 cm apart and cowpea has been planted on the top of the beds in 2, 3and 4 rows. Wheat/peas intercrops pattern has been planted on the same plots of prior intercrops. the wheat has been planted on the top of the beds in 3, 5 and 6 rows, the peas has been planted on all sides of beds .The distance between every tow beds has been 25cm.On all crops in each treatment, recommended phosphorus and potassium fertilizers have been received. Plant samples have been taken from each plot at harvesting stage to determine the yield weight of both intercrops patterns and sole crops.

Soil CO_2 emissions have been measured during the 6 growing seasons of the three successive years, taking into consideration that all different agriculture operations have been carried out during the measurements and also some precipitations has been fallen. The measurement of CO_2 emissions have been based on the static chamber technique(Zibilske,1994) in which an increasing CO_2concentration with time has been expected and referring for gas diffused from profile layers .In this technique, at the soil surface of each plot and between the rows, the transparent polyethylene plastic chamber(37x 30 x 20 cm distances) has been placed and inserted for depth of nearly 7.0 cm(without any plant under it).In each chamber, 1N NaOH solution trap (400 cm^3) has been placed. Also, centigrade thermometers to measure temperature degrees at 5 cm depth of soil surface (submerged in mud-filled glass beakers) and jars filled with water to conserve moisture level have been placed inside the chambers. The alkali traps have been changed after 7 days of starting chamber close. This work has been continued for every chamber along with every growth season (i.e the measurements have been carried out for every week) and taken to analysis in Lab. Also, the weekly averaged-readings of temperature (3 readings) have been recorded to know the warming case of chamber ambient as well as surface soil samples have been taken to determine soil moister content at the same time of alkali traps changing. The emitted CO_2 has been absorbed by NaOH. Reacted alkali in the NaOH traps with CO_2 emitted from soil forming Na_2CO_3 has been reacted chemically with added 1N $BaCl_2$ solution. Back-titration with 1N HCl and in existing of phenolphthalein as an indicator to determine the unreacted NaOH has been done(Anderson *et al*.,1982).Then, the emitted-CO_2 equivalents have been calculated by subtracting the equivalents of HCl used in back-titration(equivalents of unreacted NaOH) from equivalents of used total NaOH. Soil CO_2 emissions, soil temperature and soil moisture have been recorded weekly from October 3rd, 2010 to May9th, 2013.Measurements have been uniformly recorded at nearly hour of 12-12.30am.Cumulative CO_2 emissions for each season of 6 successive seasons have been calculated using the following relationship:

CO_2 kgfed^{-1}season^{-1} $= \sum_{i=first}^{n=last} Xi + Xi+1+ Xi+2+\ldots\ Xi+ n$

where (i) is first week of the first growing season when first CO_2 measurement has been taken , (n)is the last week of the last growing season when last CO_2 measurement has been taken, (X) is CO_2 measurement(kg fed^{-1}week^{-1}).The yield of each crop has been recorded every growing season. Before planting, soil samples from the surface layer (0-30) have been taken from the experiment site, air-dried, ground, sieved through a 2 mm sieve and analyzed for some physical and chemical properties as recorded in Table 1. After harvest, soil samples have been collected from the surface layers and sub-surface layers at soil depths of 0 – 10, 10 – 30 and 30 – 60 cm. for all plots within the studied six seasons. The soil samples have been divided into two parts. The first part has been leaved as it is (undisturbed) and used to determine the soil aggregate size distribution and total soil porosity. The second one has been air-dried, ground to pass through a 2 mm sieve and kept for the chemical determinations. Soil pH and organic matter have been determined according to the methods described by Page *et al*.,(1982).The total soluble salts (EC) has been determined in soil paste extract as dSm^{-1}(Jackson, 1973). The content of available nitrogen in soil has been determined according to the method described by Cottenie *et al*., 1982.Particle size distribution has been carried out by the pipette method described by Gee and Bauder,(1986).Soil bulk density (BD)has been determined using the un disturbed soil column and total soil porosity has been calculated as percentage from the obtained values of soil real and bulk densities according to Richards(1954). Distribution of dry aggregates has been determined according to the methods of Richards (1954).Water stable aggregates have been determined using the wet sieving technique described by Yoder (1936) and modified by Ibrahim (1964). All data have been averaged to generate mean values to facilitate their display in graphical diagrams. Statistical analysis has been carried out according to the procedures outlined by Snedecor and Cochran (1980).

Table (1): Some Physical and Chemical Characteristics of the studied soil

Depth cm	Cations Me L^{-1}				Anions Me L^{-1}			N mgkg^{-1}	O.M %	EC dSm^{-1}	pH 1:2:5	Particle size distribution			Texture
	K^+	Na^+	Mg^{++}	Ca^{++}	So^{--4}	Cl^-	HCO^{-3}					Sand %	Silt %	Clay %	
0-10	0.32	4.75	3.50	2.50	4.07	6.50	0.50	55.50	2.10	1.11	7.11	7.50	37.00	55.50	Clay
10-30	0.36	5.60	3.50	3.00	4.46	7.50	0.50	53.50	1.80	1.25	7.30	6.75	35.75	58.50	Clay
30-60	0.32	5.25	3.50	3.00	4.07	7.50	0.50	53.60	1.77	1.21	7.11	5.50	36.50	59.00	Clay

RESULTS AND DISCUSSION

Carbon exists in many forms and is the major building block for life on Earth. It is found indifferent terrestrial ecosystems. One of most important of them is agro-ecosystem, where the carbon is predominantly as plant biomass, as soil organic matter, and as the carbon dioxide gas (CO_2).The discussion of this study will allocate its situation in every one of the above sections and demonstrate how to sequester it in soil or in plant biomass influencing by the experimental work of the suggested management practices targeting to reduce the level of carbon that occurs in the atmosphere as CO_2 and to reduce the release of CO_2 to the atmosphere from agricultural soil and subsequently mitigate global warming.

1. Soil carbon dioxide (CO_2) emissions:

1.1. Under dry and wet condition.

Fig.(1) show the results of soil-CO_2 emissions released from non-irrigated (0_1) and irrigated (0_2) plot treatments-both have been uncultivated and unfertilized-which have been carried out for 6 successive seasons. Clearly, emitted-CO_2 quantities from soil have been varied influencing by variations between environmental conditions of summer and winter growth seasons and also between the non-irrigated and irrigated treatments. These quantities have been higher in summer seasons and irrigated-plot treatment than those of winter seasons and non-irrigated-one. Also, it is observed on all the studied seasons that there is fluctuation status for CO_2 values related to time intervals at which the measurements have been taken. Since such treatments have not been cultivated or fertilized, the unique effect in either seasonal variation or irrigation status has probably been the change in temperature & moisture intensities and their frequencies that affect the decomposers of organic matter stock and also their propagation, in this connection, Xu, *et al*.,(2004)stated that soil respiration (emitted CO_2) is low in dry conditions and increases to a maximum at intermediate moisture levels until it begins to decrease when moisture content excludes oxygen. Atkin *et al*.,(2000)reported that temperature will increase soil respiration exponentially to a maximum, at which point respiration will decrease to zero when enzymatic activity is interrupted.

From Table (2) it is generally illustrated that total amounts of emitted-CO_2 from both non-irrigated and irrigated-treatment & its quantity in carbon form and calculated for every season either summer or winter have been somewhat high. It is also observed that the emitted-CO_2 or CO_2-C quantities from irrigated-treatment have been higher than those of non-irrigated one where they have amounted(on averaged) 4.13ton CO_2fed^{-1}(1.12 ton CO_2-C fed^{-1})for former, and 3.63 tonCO_2fed^{-1}(0.98 ton CO_2-Cfed^{-1}) for latter with percentage difference of 13.77%, the relatively high magnitude belonging to winter emitted CO_2 may be attributed to the effect of some precipitation which have been fallen during such period on soil moister content and consequently on increase the emitted-CO_2, as well as there has been evident variation between summer and winter total measurements of CO_2 either under irrigated or non-irrigated plot treatments. For summer seasons, they have varied between 4.06(1.1CO_2-C) and 5.13ton CO_2fed^{-1}(1.39tonCO_2-Cfed^{-1}) under irrigated treatment and from 3.76(1.02 CO_2-C) to 4.41ton CO_2fed-^{1} (1.19ton CO_2-Cfed^{-1}) under non-irrigated one. For winter seasons, such values have varied between3.08 (0.83 CO_2-C) and 4.03 ton CO_2fed^{-1} (1.09ton CO_2-Cfed^{-1}) under irrigated treatment and between 2.61 (0.7 CO_2-C) and 3.74 ton CO_2fed^{-1} (1.01 tonCO_2-Cfed^{-1}) under non-irrigated one. The percentage differences between the CO_2 quantities have been emitted from soil for every season under non or irrigated treatments varied between 1.75 and 19.42%.Such values for all summers and all winters, on averaged, have been amounted 22.91 % under irrigated treatment and 26.56 % under non-irrigated one, several studies have been somewhat in agreement with these results, for example, Hanson *et al*., 1993,. Here, it must be pointed out that the soil without any usage has released some emissions of CO_2.This result would be taken into consideration because these emissions play an important role in regulation of regional and global carbon cycle, and especially at its exploitation for agricultural or industrial investments.

1.2. Under different studied treatments.

The results of different treatments (urea, UF, T_1,T_2,T_3 and T_4) effect on soil temperature (ST), soil water content (SWC) and CO_2-emitted from soil during carrying out the varied agriculture processes (fertilization, irrigation, wedding....etc) for 6 successive seasons as well as during taking place the plant growth and fallow times has been graphically recorded in Figs.(2 ,3 and 4). As for ST, it is observed from Figs. (2a, 3a and 4a) that in all summer seasons, there has been upward trend for ST degrees ranged from 27 to 45 c° while in all winter seasons, there has been downward trend for such degrees ranged from 34 to 12 c°, the noticed simple fluctuation in recoded ST degrees may be attributed to heat loss resulting from evaporation after the irrigation and then taking place solar heating again and so on .It is also observed that on most studied seasons, no difference between ST degrees under urea or UF treatments has been occurred. Under intercrops patterns (T_1 and T_2), the ST degrees have been few lower than those of sole crops (T_3 and T_4). This may be confined in the insulation effect of surface soil referring to the intercropping system; as the intercrops grow and increase their foliage, the soil surface gets covered. Ghanbari *et al*.,(2010) observed reduction in ST in plots with maize-cowpea intercropping compared to those with sole maize stand. He explained this as due to the shading effect of two crops in the intercropping system

Figs.(2b, 3b and 4b) also, record the SMC results under different treatments which illustrated that: firstly, the soil moisture content in winter seasons has been greater than that of summer seasons where their levels have been ranged from 5 to 55% for former and from 2 to 32% for latter, such effect has been a reflection for variation of evaporation status in different seasonal climate. Secondly, the marked fluctuation in levels of SMC in all diagrams may be due to the case of wetness and dryness which always occurred after every time of irrigation or due to the depletion of moisture resulting from water absorbance by crops or water drainage and dryness of surface soil .Thirdly, levels of SMC under both UF and urea treatments has been approximately equated. Fourthly, no certain trend for the effect of intercrops or sole crops on SMC levels has been seen; such levels have sometimes been increased under T_1 and T_2 and sometimes under T_3 and T_4 and vice versa, this may be related to the effect of all gathered factors (wetness, dryness, shading and water absorbance...etc).

From Figs.(2c,3c and 4c),it is in general, illustrated that the curves of CO_2 released under all treatments have taken a pattern of maximized or minimized CO_2 values ,probably, influencing by different effective factors such as agriculture processes or others (pH, EC , aeration, clay,...etc) which appear to be more impact (amongst increase or decrease) on the mineralization capacity of the soil organic matter and CO_2 release or the root respiration or the biological activity in this experiment, because no consistency between the seasonal patterns of ST degrees or SMC and those of emitted-CO_2 have been realized. It is observed an increasing CO_2 released under almost treatments at the intermediate weeks of every season where this periods have related to maximum growth of crops either above or below ground, in another words, increasing growth, activity and respiration of the roots which may be varied accordingly, their type and nature. Also, in all studied seasons, CO_2 emissions from urea treatment has been surpassed to those of UF one, which may be attributed to high availability of nitrogen in urea case and its effect on the decomposers of organic matter as well as CO_2 emissions from T_1 and T_2 (intercrops) have sometimes been slightly higher than those of T_3 and T_4 (sole crops), this is expected due to the higher roots dense for former treatments comparatively to those of latter ones and its effect on their respiration. The most minimum amount of CO_2 emitted (may lag period) has been only noticed in first weeks of first season of first year and some extent, after harvest (fallow period). In this section of discussion, it is obviously shown the effect of fertilization types, irrigation, varied density of roots systems of intercropping patterns and seasonal changes. Similar results have been obtained by several studies for example, Makumba *et al*.,(2007) , Iqbal *et al*.,(2008) and Ussiri and Lal (2009).

Correlation analysis has been undertaken between soil CO_2 emissions and ST and SMC to determine the relationships between such emissions and each one for non-irrigated and irrigated plot treatments (Fig.5) and under different treatments (Figs.6, 7 and 8).

From Fig. (5), on all six studied growing seasons, it can be seen that there have been negative weak correlations or no correlation between CO_2 emissions and each one of ST and SMC under non-irrigated or irrigated plot treatments, where R^2 ranged from 0.001 to 0.282 for former and from 0.0002 to 0.2799 for latter. However, slight increase in R^2 values belonging to ST of non-irrigated plot has been observed. The mixed results without limited trend for R^2 of SMC have been obtained. It is appear that conflated effects for both ST and SMC have necessitated the soil biological system to give such results .These tendencies have been in accordance with findings of Xu *et al*., (2008). From Figs.(6 ,7 and 8),it is also found that for all studied seasons , no correlation or weak correlation between CO_2emissionsand ST under urea or UF treatment;R^2 for former ranged from 0.003 to 0.40 and ranged from0.002 to 0.05 for latter.

Under intercropping and sole crop patterns (on average);R^2 have ranged from 0.004 to 0.3409 for former and ranged from 0.002 to 0.3664for latter. These results have been in agreement with Huang et al., (2013). Obviously, poor dependence for soil CO_2 emissions on soil temperature and moisture has been occurred. Apparently, the results of soil CO_2 emissions have been affected by a very complex interaction of several factors and related to them more than soil temperature and moisture.

2. Crop production and crop carbon sequestration

2.1Crop production

The results in Table (3) show the effect of sunflower/cowpea intercropping system for 3 cultivating seasons and N-fertilizer treatments on crop yield and biomass carbon (biomass-C). There has been significant positive effect ($p < 0.05$) for intercropping configurations on sunflower stalks & seeds yield, cowpea yield and total yield of both crops at the 3 cultivating seasons. Limited significant variation has been observed for N-fertilization on the same parameters. Non significant effect has been recorded for interaction between intercropping system configurations and N-fertilization on the previous mentioned parameters.

Because of plants act as a bridge to carrying the carbon from atmosphere where they use their primary function (photosynthesis) to produce plant biomass as a precursor soil organic carbon input, crop yield data have been calculated as biomass-C (biomass-C ton fed^{-1} = crop yield in ton fed^{-1} x 0.58).Averaged seasonal biomass-C values have ranged from 13.06 to16.10ton C fed^{-1}season^{-1}and amounted 41.78 ton C fed^{-1} as a total biomass-C for 3studied seasons. The significant effects of intercropping systems, N- fertilization and interaction on biomass-C have taken the same directions of such effects on crop yield at the 3 cultivating seasons as well as on total crop yield and total biomass-C of 3 seasons.

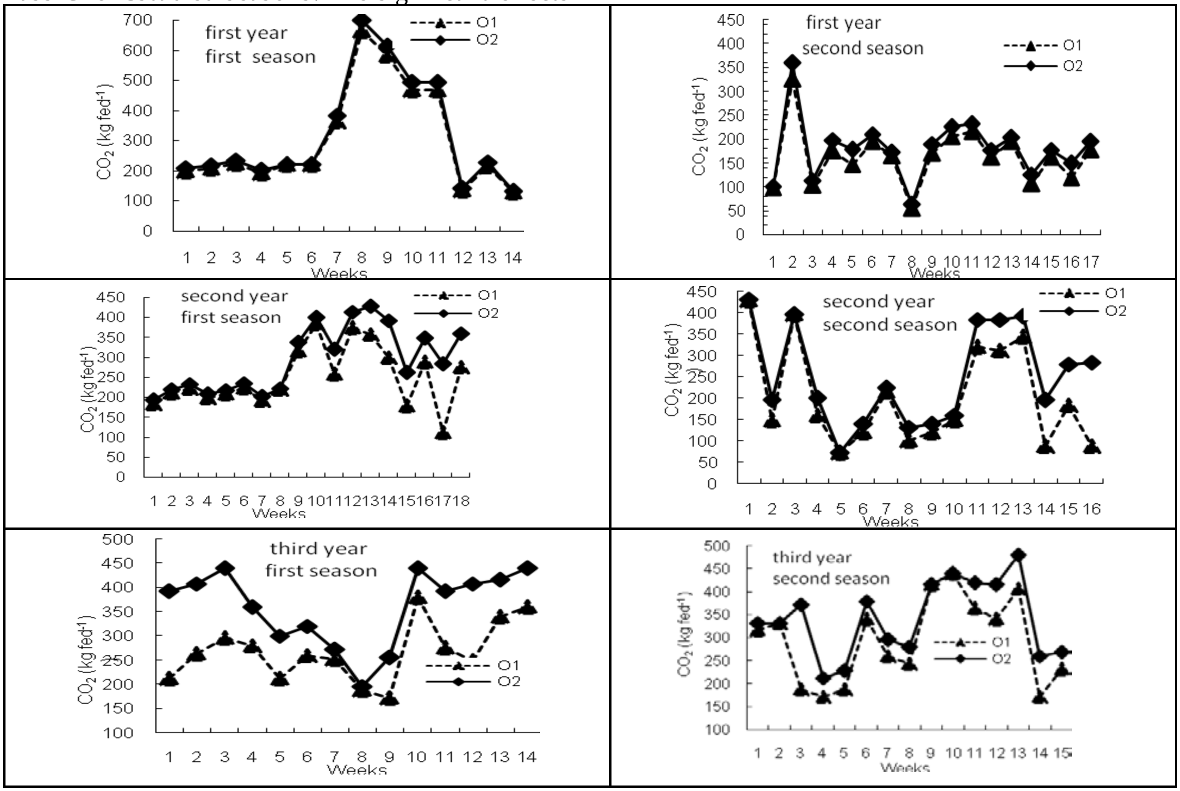


Fig.(1): CO$_2$ emissions released from soil under dry and wet conditions for 6 seasons of 3 successive years

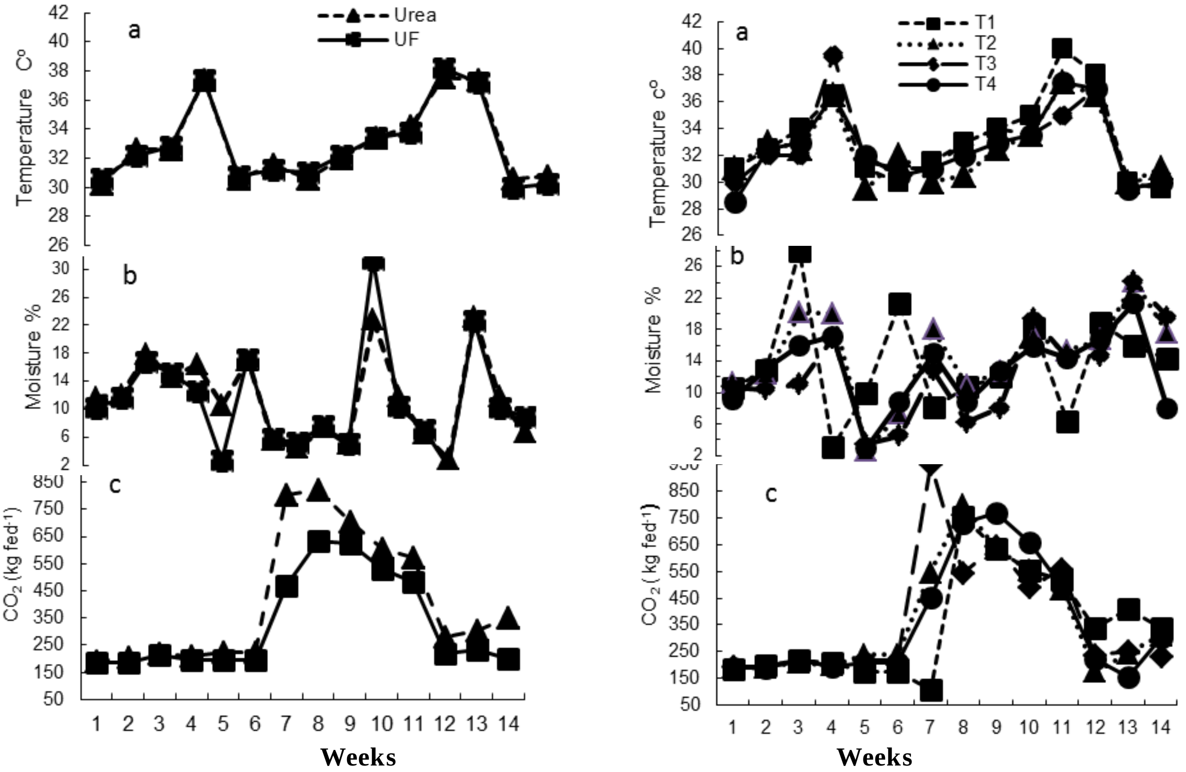
Table (2): Total soil CO$_2$emissions and its quantity in carbon form (tonfed^{-1})of 6successiveseasons for non-irrigated and irrigated plot treatments

Treatment plot	Season	Summer 1	Winter 2	Summer 3	Winter 4	Summer 5	Winter 6	Mean of Summers	Mean of Winters	Mean of Irrigation status	Summers, Winters Difference%
							(tonfed^{-1})				
Non irrigated	CO$_2$	3.99	2.61	3.76	3.24	4.41	3.74	4.05	3.20	3.625	26.56
	CO$_2$C	1.08	0.70	1.02	0.88	1.19	1.01	1.09	0.86	0.98	
Irrigated	CO$_2$	4.06	3.08	4.49	4.01	5.13	4.03	4.56	3.71	4.13	22.91
	CO$_2$C	1.1	0.83	1.21	1.08	1.39	1.09	1.23	1.00	1.12	
Difference %		1.75	18.01	19.42	23.77	16.33	7.75	12.59	15.93	13.77	

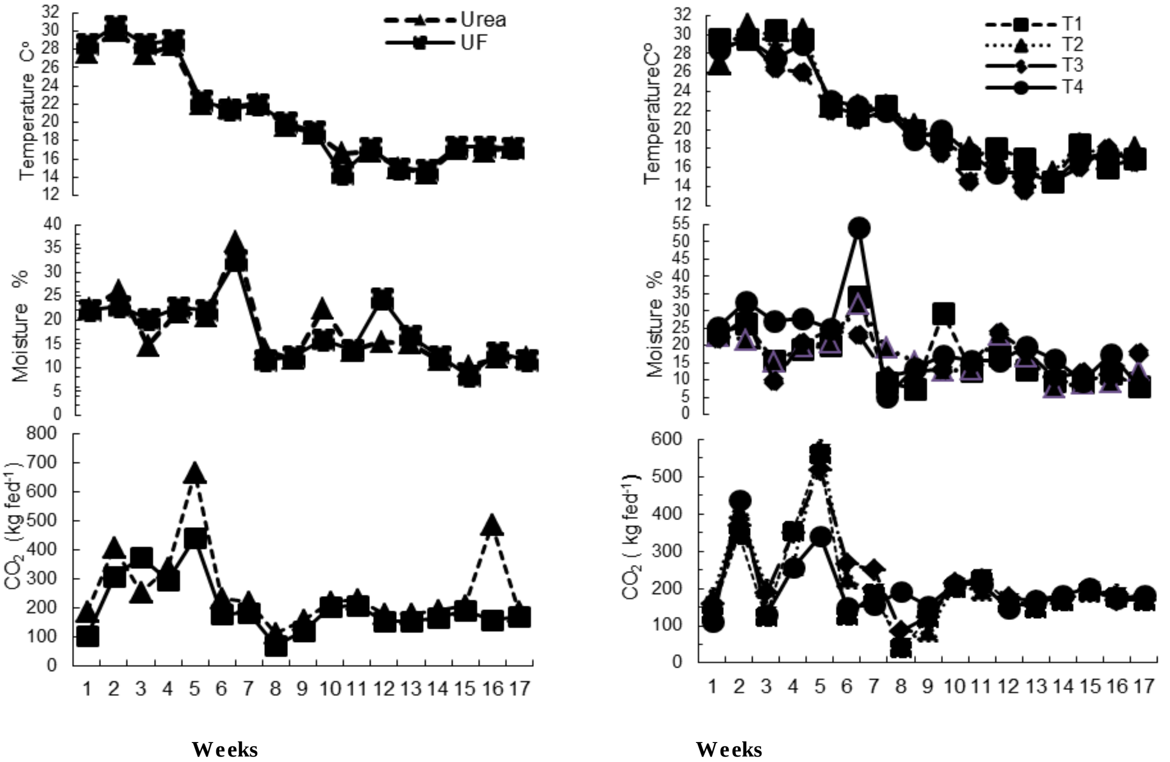
Taking the averaged biomass-C values influenced by intercrops (T_1&T_2) and sole crops (T_3&T_4), it is demonstrated that averaged value of former has been obviously superior to those of latter where the averaged-values of intercrops have ranged from 16.07to18.63 tonCfed^{-1}season^{-1}while they have ranged from 9.71 to 13.57 ton Cfed^{-1}season^{-1}for sole crops over the studied 3seasons. The total biomass-Quantities of averaged-value for intercrops have amounted 11.53 ton Cfed^{-1}and amounted 7.72ton Cfed^{-1}for sole crops pattern. The values of biomass-C relative increase for intercrops to sole crops have ranged from 37.29 to 68.88% over the studied 3 seasons and it has amounted 51.77% at total biomass-C for 3studied seasons.

Data presented in the same Table show reasonable superiority for the averaged biomass-C values referring to UF fertilizer to those of urea fertilizer. These values for former have ranged from13.28 to16.66 ton Cfed^{-1}season^{-1}and ranged from 12.82 to 15.54 ton Cfed^{-1} season^{-1}for latter over the 3studied seasons. The total quantity of averaged-biomass-C value of UF fertilizer has amounted 42.13 ton Cfed^{-1}. Such value for urea fertilizer has amounted 40.56ton Cfed^{-1}.Also, biomass-C relative increase values for UF to urea have ranged from 3.59 to 7.23%.It has amounted 3.86% as a total of averaged-values for 3 studied seasons. Most works that deal with intercrops &sole crops patterns have recorded clear superior crop biomass for former to latter, for example , Natarajan and Willey(1986),Ajeigbe *et al.*,(2008) and Latati *et al.*,(2013).Also, several studies confirmed on the superiority of crops yield fertilized with UF to those fertilized with urea, for example, Abbady *et al.*,(2011) and Abbady *et al.*,(2013).

From Table (4), it can observed that the effect of wheat / peas intercropping system for 3cultivating seasons and N-fertilizer treatments on crop yield and biomass-C values has been markedly lower than that of previous mentioned intercrops pattern (Table 3).There has however been clear significant difference for intercropping configurations on wheat, peas ,total yield for every season and total yield of 3 seasons. Also, there has been positive significant difference between the different treatments on biomass-C for every season and also for total biomass-C of 3 seasons. Averaged seasonal biomass-C values have ranged from 3.17 to 3.3 and amounted 9.63 ton C fed^{-1}season^{-1}for 3 seasons. Averaged biomass-C values have ranged from 3.79 to 3.99 ton C fed^{-1}season^{-1} for intercrops pattern and ranged from 2.55 to 2.7 ton C fed^{-1}season^{-1} for sole crops pattern. Also, biomass-C relative increase for intercrops to sole crops values have ranged from 44.45 to 52.99 % and amounted 49.38 % for 3 seasons. The biomass-C values have been influenced by N-fertilizer types where they have ranged from 3.06 to3.23 ton Cfed^{-1}season^{-1}for urea and from 3.28 to 3.49 ton Cfed^{-1}season^{-1}for UF and amounted 9.23 for former and 9.97 ton C fed^{-1}season^{-1}for latter. Preponderancy of UF as slow release fertilizer has been realized through calculation of biomass-C relative increase for UF to urea which has ranged seasonally from 4.50 to 12.2 % and amounted 8.05% for 3 seasons. The trend of these findings has been seen in previous pattern (table 3). However, crop yield of this intercrops pattern (table 4)has been lower than those in previous mentioned above which may due to the variation in crops type, in particular , the lower yield for peas which may be attributed to severe competition with wheat for light, the same findings reported by Singh and Ajeigbe(2007).

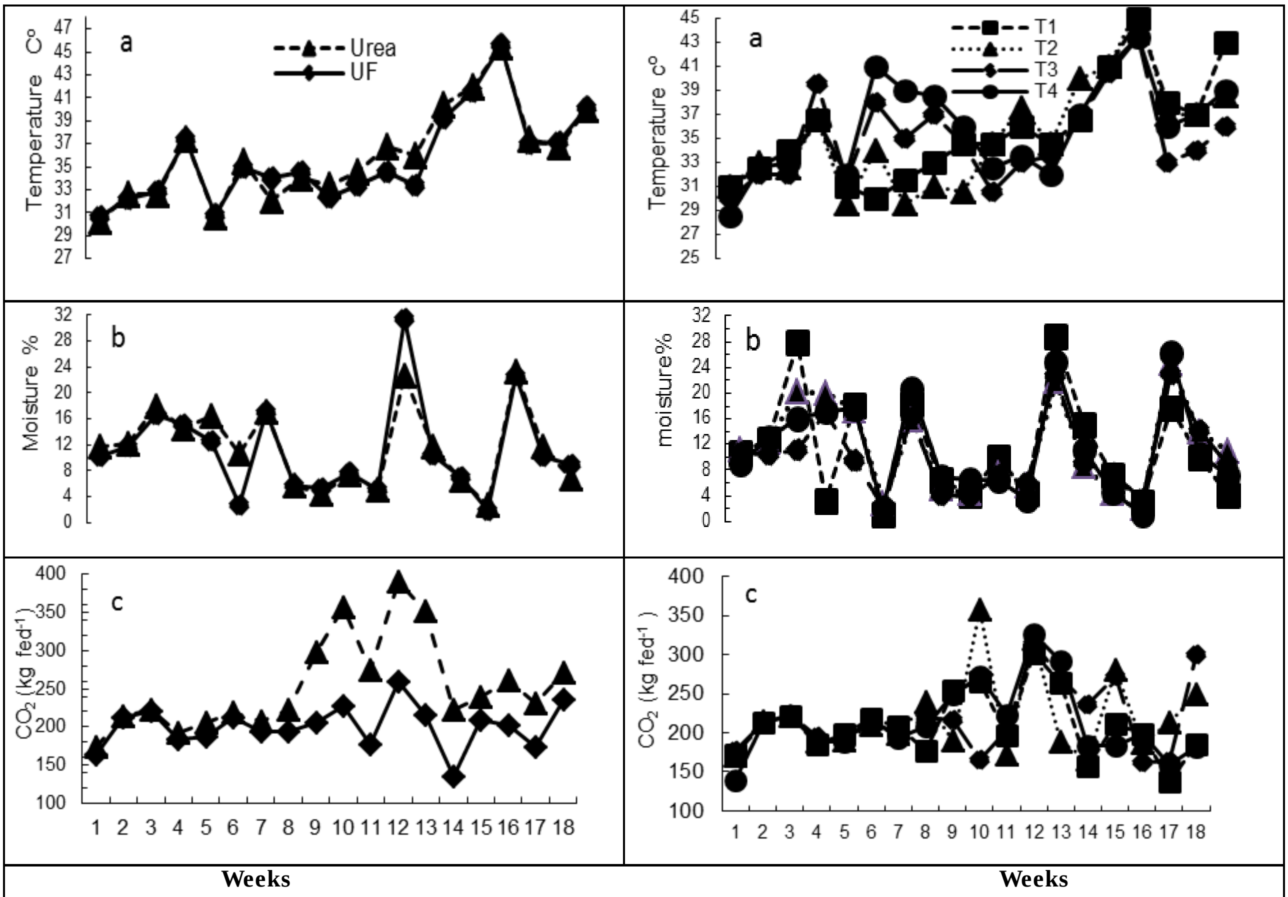


First season of first year, summer 2010

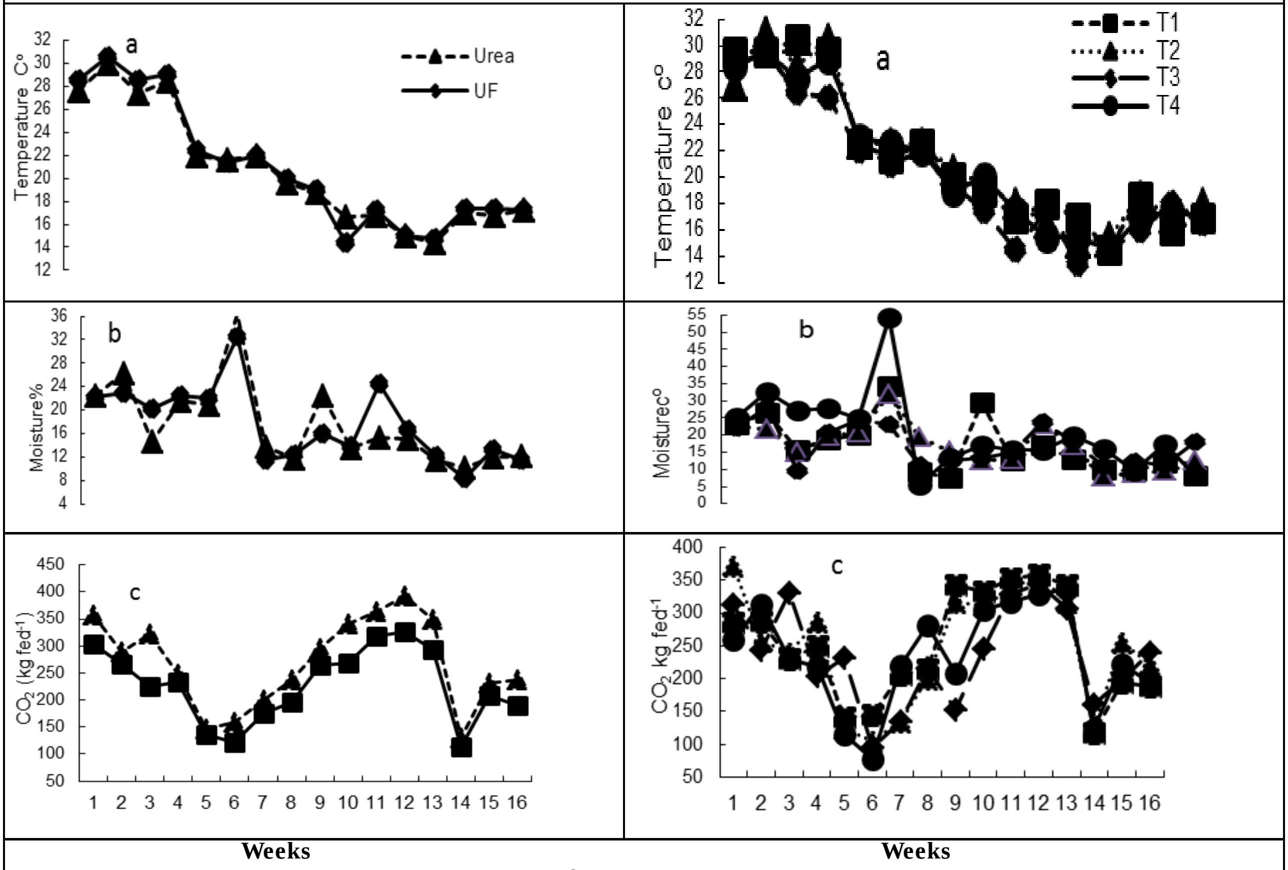


Second season of first year, winter 2010-2011

Fig.(2): Soil temperature (a), soil moisture (b) and soil emitted CO_2 (c) at different treatments during first year of 3 successive years.



First season of second year summer 2011



Second season of second year, winter 2011-2012

Fig.(3): Soil temperature (a), soil moisture (b) and soil emitted CO_2 (c) at different treatments during second year of 3 successive years.

Crop carbon sequestration

To assess the management practice pursued in this study as a tool to sequester absorbed- carbon from atmosphere in crop biomass, the equation reported by Baldocchi and Valentini (2012) has been applied: *NEP = GPP – Reco*

where: *NEP* is net ecosystem productivity and is defined as the difference between gross primary productivity (GPP) or plant biomass carbon representing the carbon dioxide amount that is assimilated by plants through photosynthesis and ecosystem respiration (R_{eco}) or, here, soil emitted carbon.

Tables (5 and 6) contain all the outputs of this experiment in carbon form; the former will have the results of sunflower/cowpea intercrops and the latter have wheat / peas intercrops. The results given in Table 5 represent the total carbon yield of different intercropping configurations, total (cumulative) emitted CO_2& their values in carbon form, sequestered carbon for every season and its final resultant of the 3 seasons which reveal that, in all studied seasons: Firstly, the intercrops patterns (T_1andT_2) as a carbon values have been superior to those of sole crops patterns (T_3andT_4) and statistically have had positive significant effect. The carbon which has been collected from atmosphere by former ranged from 15.38 to 18.78ton Cfed^{-1}and ranged from 9.38 to 13.57ton C fed^{-1}by latter.

This effect has been expected and due to the higher obtained yield of intercrops patterns. Secondly, soil emitted CO_2 values under intercrops patterns (T_1 andT_2) have been slightly inferior to those of sole crops (T_3 andT_4)where these values have ranged from2.04(1.1 CO_2-C ton fed^{-1})to4.84 ton CO_2 fed^{-1}(1.31 CO_2-C fed^{-1}) under former and from 3.91(1.05CO_2-C ton fed^{-1})to 5.15 ton CO_2fed^{-1}(1.39CO_2-C tonfed^{-1}) under latter, their final resultant of the 3 seasons ranged from3.38to3.47 CO_2-C tonfed^{-1}for former and from 3.63 to 3.64 CO_2-C ton fed^{-1}for latter. Thirdly, sunflower-cowpea intercrop carbon values related to urea treatments(on average) have been inferior to those of UF treatments, such values have ranged from 12.60 to15.27ton CO_2-C fed^{-1}for former and ranged from13.06 to 16.38 ton CO_2-C fed^{-1} for latter. Fourthly, soil emitted CO_2 values related to urea treatments (on average) have been superior to those of UF treatments where these values have ranged from 4.39 to 5.58tonCO_2 fed^{-1}(1.19 to1.51 ton CO_2 -Cfed^{-1}) for former and from3.80 to4.32ton CO_2 fed^{-1}(1.03 to1.17ton CO_2-Cfed^{-1}) for latter. Fifthly, crop sequestered carbon values have been influenced significantly by intercropping configurations, urea and UF treatments; the data demonstrate that the averaged sequestered-C values of intercrops have seasonally ranged from14.74 to17.01ton CO_2-Cfed^{-1}and their final resultant amounted 46.76ton CO_2-Cfed^{-1}for 3 seasons while such values for sole crops have seasonally ranged from 8.45 to11.97 ton CO_2-Cfed^{-1}and their final resultant amounted 29.58 ton CO_2-Cfed^{-1}.Thereby, sequestered-C relative increase for intercrops to sole crops values have ranged seasonally from 42.06 to 77.75% and amounted 58.06 % for the 3seasons.The crop sequestered carbon values belonging to UF fertilizer have ranged from12.12 to15.21ton CO_2-Cfed^{-1}and amounted 39.70ton CO_2-Cfed^{-1}for the 3 seasons. Such values for urea fertilizer have ranged from11.35to13.76ton CO_2-Cfed^{-1} and amounted 36.64 tonCO_2-Cfed^{-1}for the 3 seasons. On this basis, the sequestered-C relative increase for UF to urea seasonally have ranged from 6.78 to 10.51% and amounted 8.35%for the 3 seasons

Dealing with data in table 6 as dealt with data in Table (5),it can be noticed that: firstly, there has been obvious effect for intercrops($T_1$and T_2) on carbon collected from atmosphere more than did with sole crops(T_3 and T_4) where such carbon values have seasonally ranged from 3.43to 4.26 tonCO_2 -Cfed^{-1}for former and from 0.54 to 4.59ton CO_2-Cfed^{-1}for latter. Secondly, insignificant differences between the carbons of both crops as affected by urea or UF fertilizer have been observed. Thirdly, slight and insignificant differences have been found between soil emitted CO_2 regarding intercrops treatments and those of sole crops ones. Fourthly, soil emitted CO_2 values of urea treatments (on average) have been more than those of UF fertilizer. Fifthly, averaged crop sequestered carbon referred to intercrops patterns have seasonally ranged from 2.45 to2.97ton CO_2-Cfed^{-1}and that of sole crops ranged from 2.43 to 3.19 ton CO_2 -Cfed^{-1}and the carbon final resultant of 3 seasons have amounted 8.06 - soil emitted carbon, tonfed^{-1}ton CO_2 -Cfed^{-1}for former and 8.62 ton CO_2 -Cfed^{-1}for latter. The sequestered-C relative increase for intercrops to sole crops have ranged from -6.72to 0.46 % and amounted -6.55 for 3 seasons. the sequestered carbon related to urea and UF fertilizers, ranged from 1.7 to1.98 ton CO_2 -Cfed^{-1} for former and from1.95 to 2.58 ton CO_2 -Cfed^{-1} for latter. The final resultant has amounted 5.56 ton CO_2 -Cfed^{-1}for former and 6.81 ton CO_2 -Cfed^{-1} for latter. The sequestered-C relative increase for UF to urea has ranged from 14.6 to30.05% and amounted 22.45% for 3 seasons. Here, it must be pointed out to the clear difference between the magnitude of sequestered-C belonging to the two intercrops patterns which may be attributed to the nature and type of used crops.

Carbon emitted from N-fertilizer manufacture

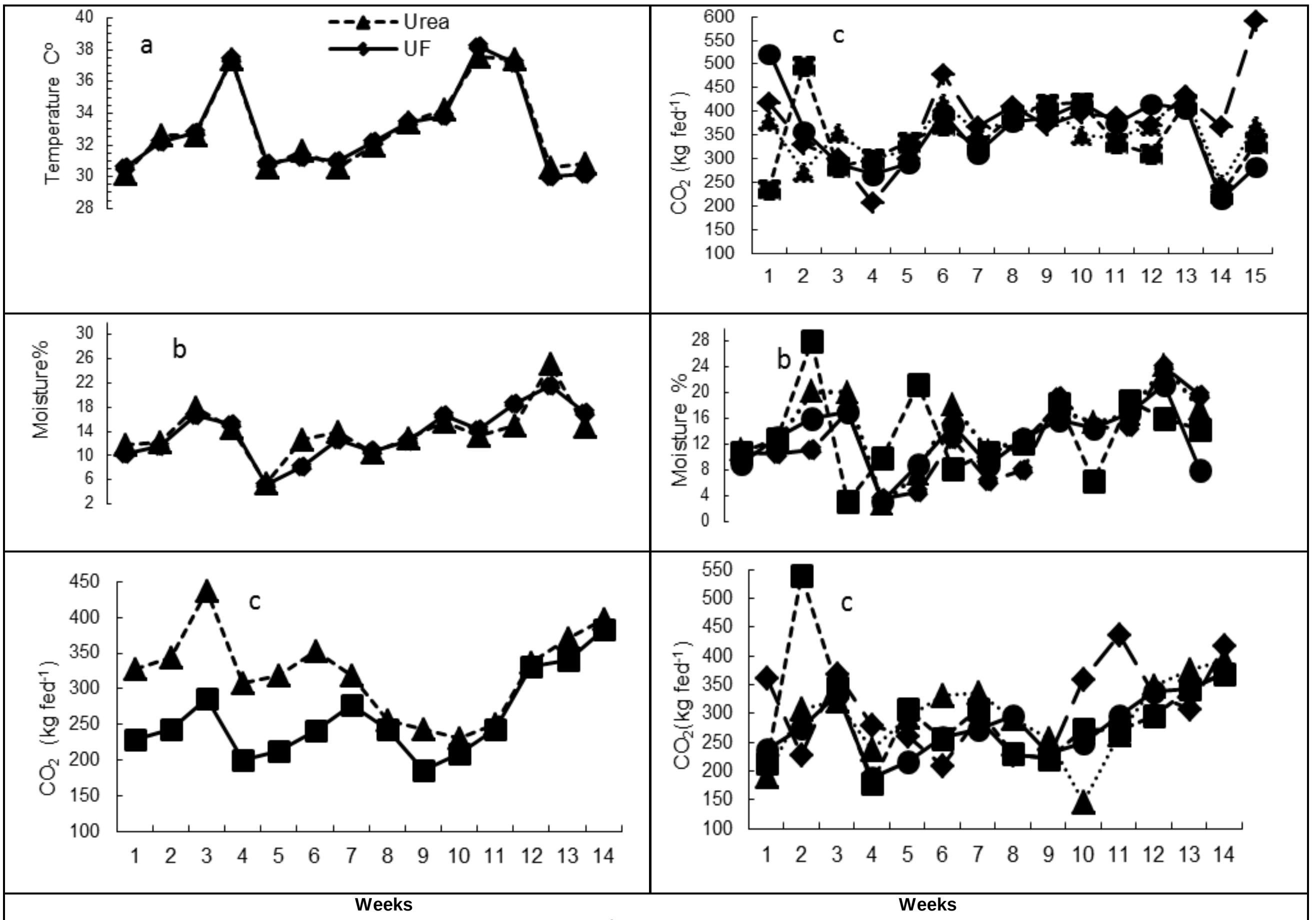
According to data reported by Lal *et al.,* (1998) that the N-fertilizer manufacture indirectly resulted in about 0.82 kg CO_2-C emission per kg N produced. Such emissions have been formed as a result of combustion of used fossil fuel to manufacture. Therefore, the values of CO_2-C emissions produced during manufacture N-fertilizers, calculated in ton fed^{-1} for one year (2N additives) and then, for three years (6N-additives), found in Table (7).They have ranged from 0.172 to 0.418 ton fed^{-1} for urea at one year and ranged from 0.738 to 1.26 ton fed^{-1} at three years. Such values for UF have ranged from 0.123 to 0.246 ton fed^{-1} at one year and from 0.369 to 0.738 ton fed^{-1}for 3 years.CO_2-C emissions from application of urea have been greater than those of UF with nearly from 1.4 to 2 times. This effect certainly attributed to the style of use of each where the former has been added for every season while the latter has been added for every 2 seasons, because it has the ability to continue in releasing its nitrogen all long the growing season. If it is the quantities of CO_2-C emitted from soil of every treatment (Table 5 and Table 6) have been added to those of fertilizers corresponding treatments ,it would be illustrated that the amounts of CO_2- C released from treatments fertilized with urea have been greater than those fertilized with UF. Similar results have been obtained by Abbady *et al.,* (2011) and Abbady *et al* .,(2013).

3.Soil carbon sequestration and affecting soil properties:

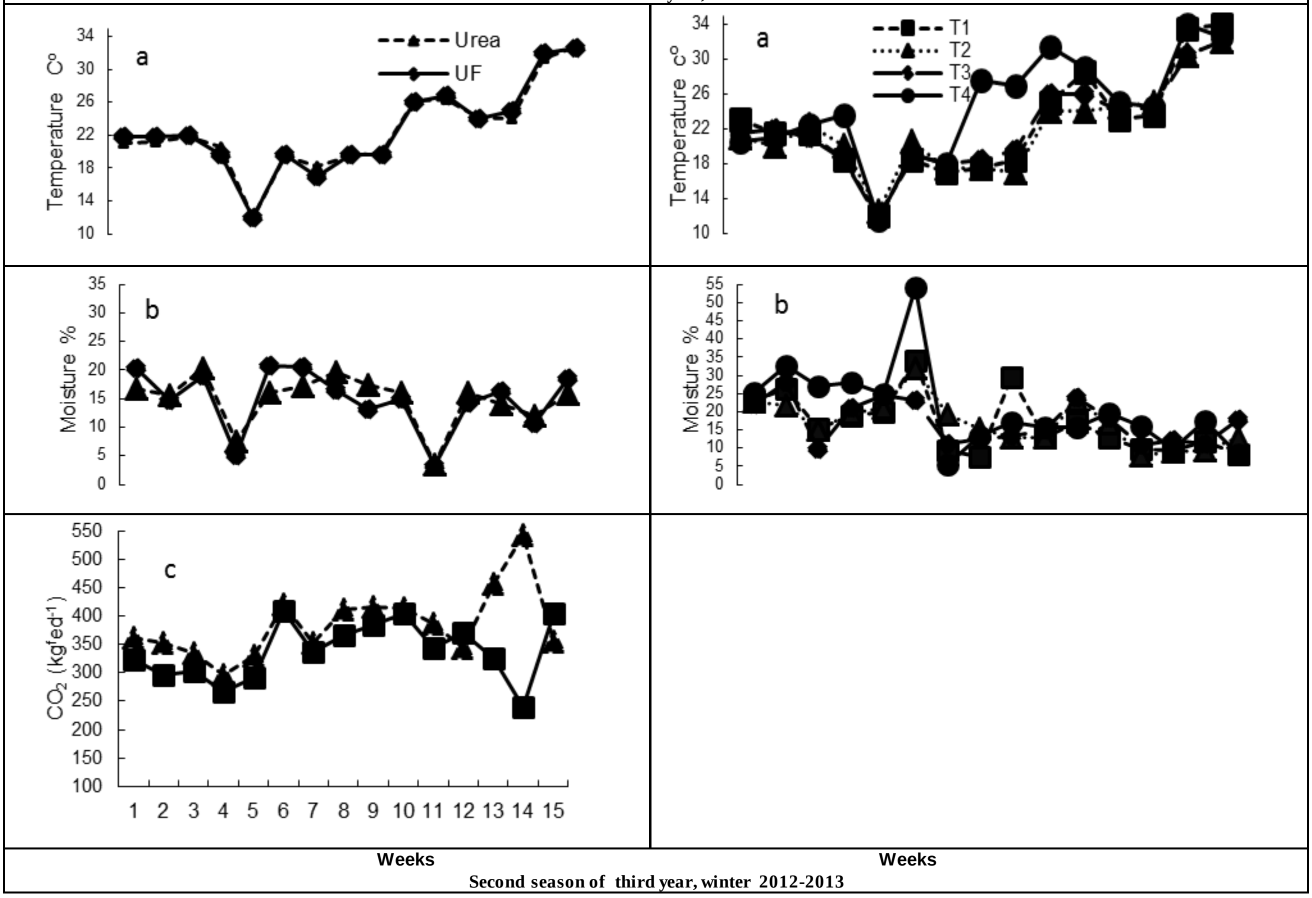
:Because of soil organic C pool has a great potential to sequester naturally a lot amounts of atmospheric carbon, the stability of organic C in soil is a prime requirement. So in this section, the discussion of implicated SC amounts and factors controlling such stability (physicochemical properties) has been devoted.

Soil carbon sequestration

Table (8) includes the change in organic matter % (OM%) ,cumulative carbon % and the sequestered-carbon (SC) throughout the experiment (6 seasons) in 3 successive soil layers (0-10,10-30 and 30-60 cm) as affected by different treatments. Generally, it is observed that the OM% change has been very slow and in little quantities, this may be due to either it is natural phenomenon related to different decomposition factors or no additional organic manure has been achieved in this study. Also, it would be mentioned that the reduced-tillage practice (undisturbed soil) has been pursued which it may be led to ensure the originally found humus compounds, in addition to roots decomposition within the experimental period. OM% change levels tend to be variable and dependent on intercrops & sole crops patterns and also on urea & UF fertilizer treatments as well as its values have varied with different depths



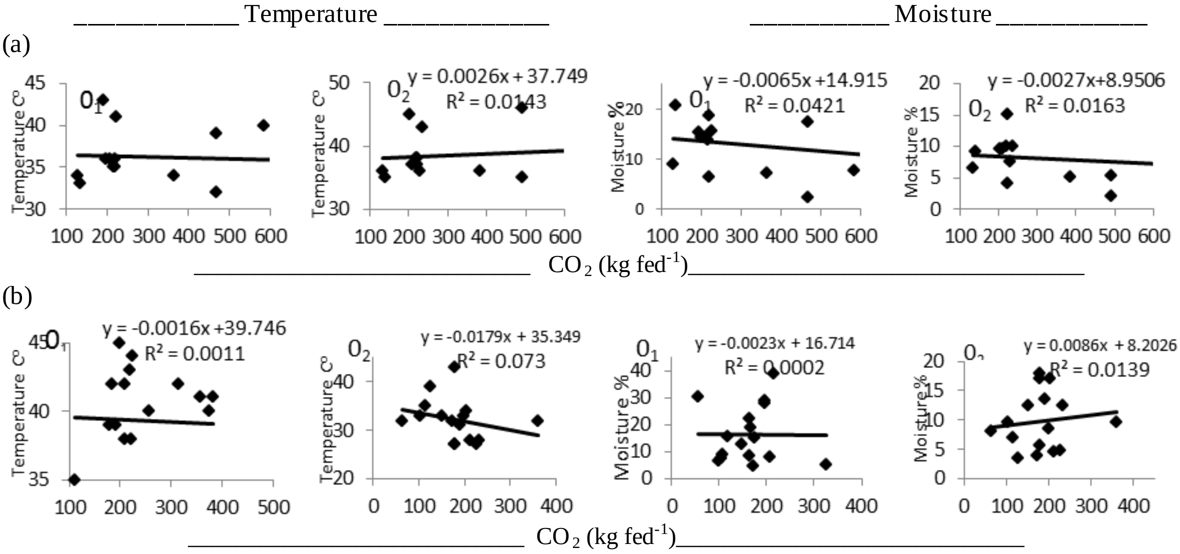
First season of third year, summer 2012



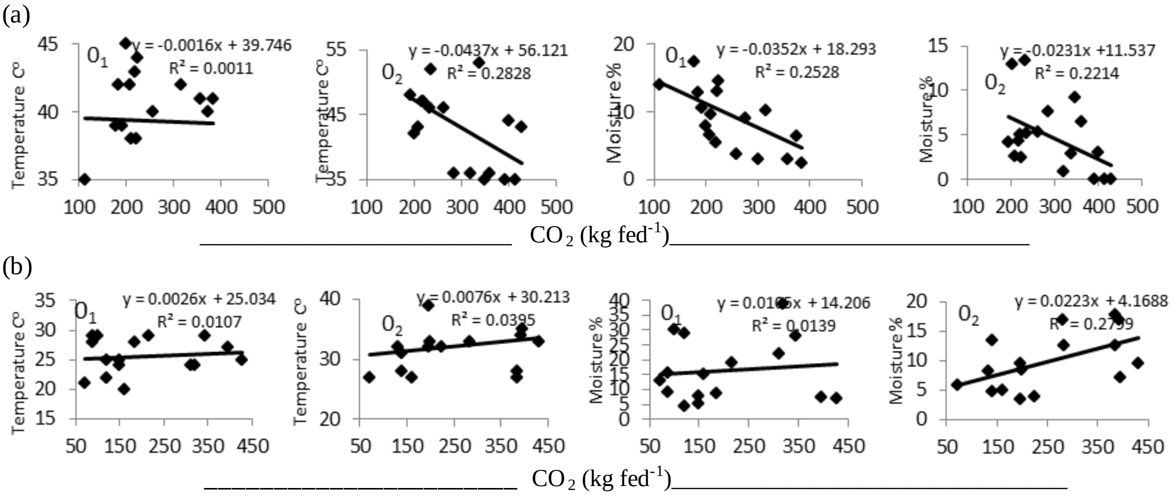
Second season of third year, winter 2012-2013

Fig.(4): Soil temperature (a), soil moisture (b) and soil emitted CO_2 (c) at different treatments during third

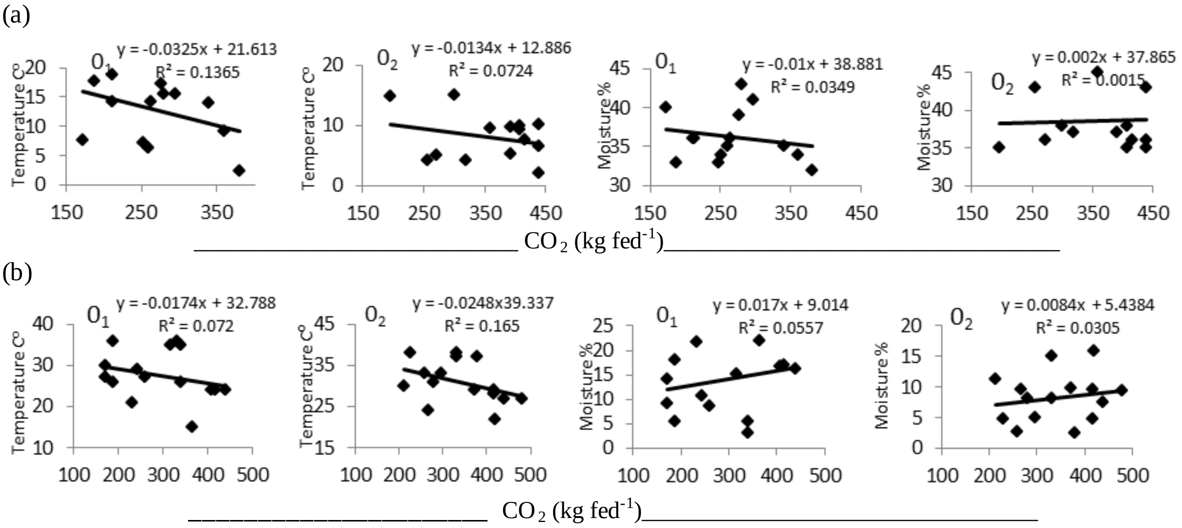
year of 3 successive years



CO$_2$ emissions for first year



CO$_2$ emissions for second year



CO$_2$ emissions for third year

Fig.(5): Correlation between CO$_2$ emissions and soil temperature and soil moisture content under dry and wet conditions at every first season (a) and every second season (b) of 3 successive years

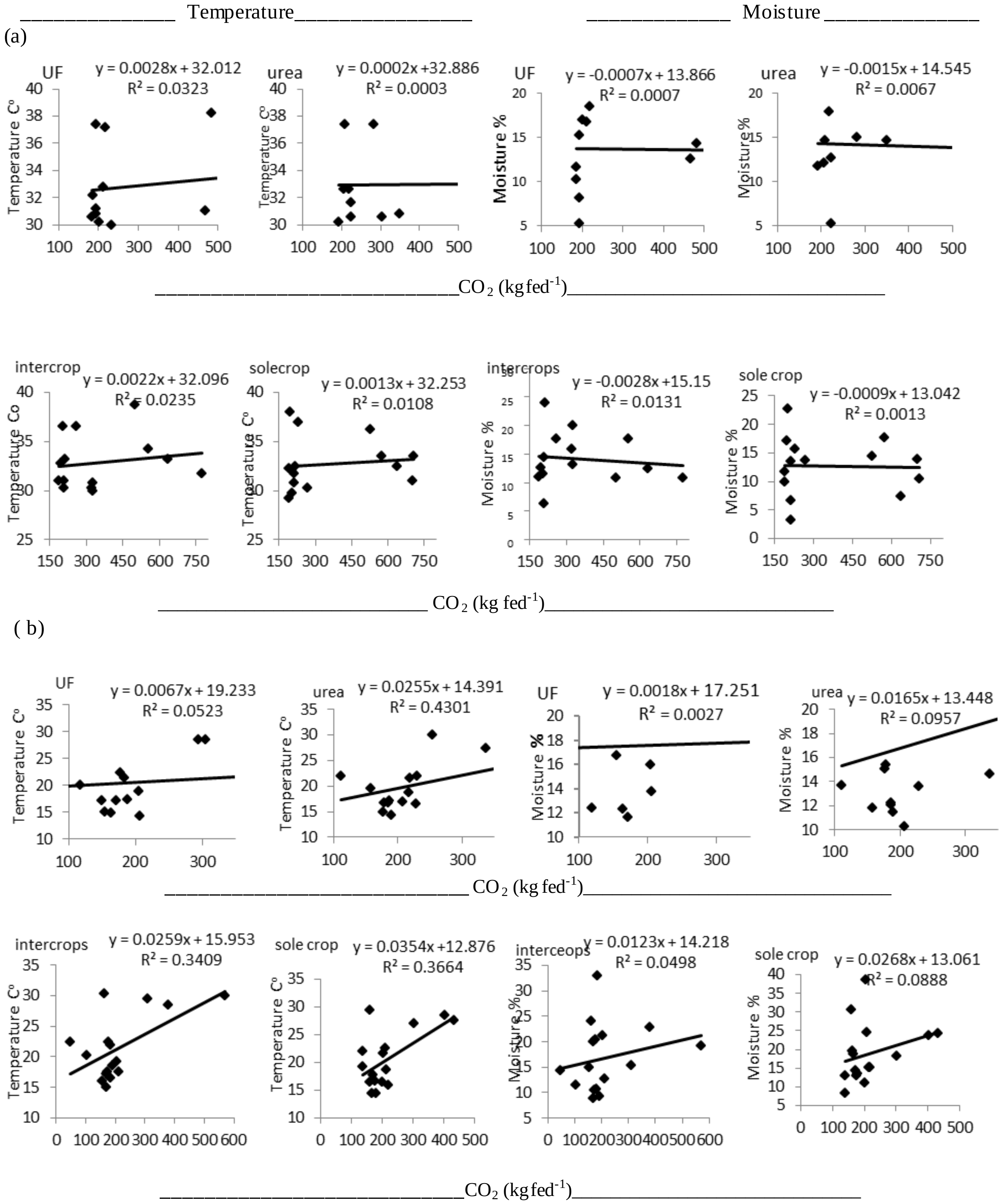


Fig.(6): **Correlation between CO_2 emissions and soil temperature and soil moisture content under different studied treatments at first season (a) and second season (b) of first year. 2010-2011**

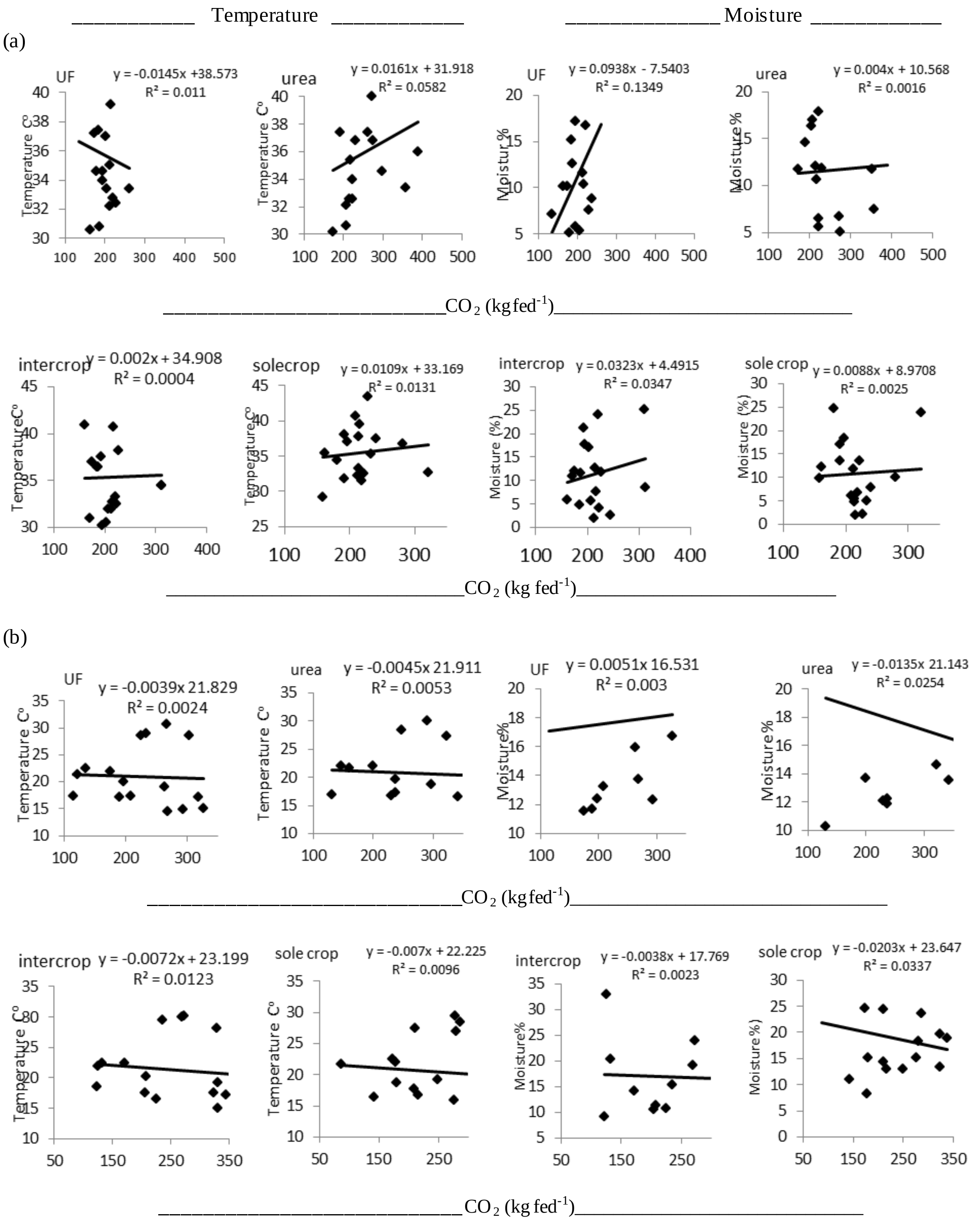


Fig.(7): Correlation between CO_2 emissions and soil temperature and soil moisture content underdifferent studied treatments at first season (a) and second season (b) of second year. 2011-2012

As for intercrop & sole crop patterns, the data given in the same Table have represented the averaged OM% change values of intercrops (T_1 andT_2) & sole crops (T_3 andT_4) patterns regardless of their crops type, as represented the sum of OM% quantities for the 3 studied layers. Averaged OM% change values have been ranged from 0.30 to 0.31 for intercrops pattern and from 0.26 to 0.36 for sole crops, and consequently cumulative carbon % values have ranged from 0.174 to 0.198 for former and from 0.151 to 0.206 for latter within 6 cultivation growth seasons. Also it is noticed that these quantities have almost concentrated in the surface layers. As matter of fact SC values under different treatments, they have been calculated based on an equivalent soil mass (Jun Ke Zhang *et al.* 2011) using the equation of : *SC,tonfed*$^{-1}$*= fed. area (* m^2*) x layer depth (m) x OC% x BD (Mgm*^{3}*)*

The data illustrate that SC values of intercrops pattern (sum of 3 successive layers) have been slightly superior to those of sole crops, where SC values of former have ranged from 1.111 to1.304 ton^{-1}fed and ranged from 0.929 to1.352tonfed^{-1} for latter, the equivalent values of SCO_2 have ranged from 4.11 to 4.826tonfed^{-1} for former and ranged from 3.438 to 5.013ton^{-1}fed for latter . Averaged sequestered-C of intercrops value has amounted 1.208 tonCfed^{-1}and amounted 1.141ton Cfed^{-1}for sole crops .SC relative increase for intercrops to sole crops has amounted 5.828%. However, the data show inferior values for SC-calculated as a percentage of sum layered-SC in top soil for former to those of latter. This may attributed to the roots distribution nature of the cultivated crops in the study. In this respect, Makumba *et al* .,(2007)stated that after 10 years of continuous cultivation of sole maize & intercropping gliricidia-maize, SC in the soil (0–200 cm, depth) of gliricidia-maize was 1.6 times more than of sole-maize. Cong WF, *et al.,* (2015), in their 7 years field experiment , found that soil organic C content in the top 20 cm was 4% ± 1% greater in intercrops than in sole crops and total root biomass in intercrops was ,on average, 23% greater than the average root biomass in sole crops. To demonstrate the roots importance for soil carbon sequestration process, Buyanovsky and Wagner (1997) concluded from their study that for many plants, as much as 30–50% of the C fixed in photosynthesis is initially translocated below-ground. Some is used for structural growth of the root system, some for autotrophic respiration, and some is lost to the surrounding soil in organic form (rhizo deposition), either sloughed during root expansion or excreted in a variety of compounds.

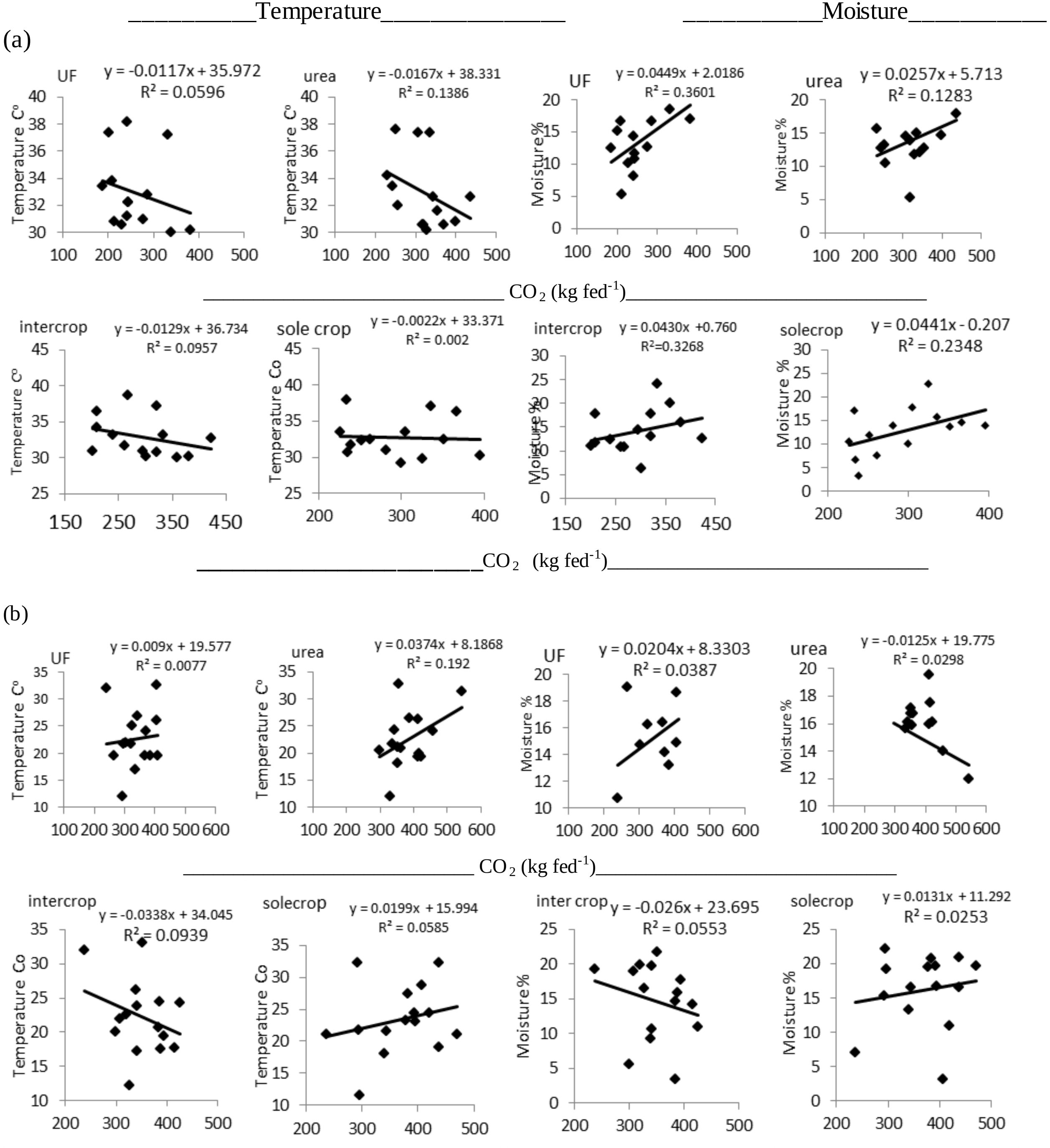


Fig. (8): Correlation between CO_2 emissions and soil temperature and soil moisture content under different studied treatments at first season (a) and second season (b) of third year. 2012-2013

Table (3): Effect of sunflower/cowpea intercropping system and nitrogen fertilizer type on crop yield and biomass carbon (biomass-C) for different treatments during the cultivated summer seasons of 3 years (2010-2011, 2011-2012and 2012-2013)

Treatments				Yield (Ton fed-^{1})															Total yield of 3 seasons ton. fed^{-1}	
Intercropping system (A)				first season, 2010-2011					second season, 2011-2012					third season, 2012-2013						
				sunflower		cowpea	Total		sunflower		cowpea	total		sunflower		cowpea	total			
Symbol	Sunflower row	Cowpea row	N. type (B)	Stalks Yield	Seeds Yield	Yield	Crop yield	biomass - C	Stalks Yield	Seed Yield	Yield	Crop yield	biomass-C	Stalks Yield	Seed Yield	Yield	Crop Yield	biomass - C	Crop yield	biomass - C
			urea	16.33	1.66	12.13	30.12	17.47	13.77	1.40	11.50	25.27	14.66	15.17	1.50	11.39	28.05	16.27	83.44	47.56
T$_1$	2	2	UF	17.50	1.70	13.07	32.27	18.72	14.14	1.44	11.71	27.29	15.83	15.87	1.56	11.74	29.16	16.91	88.71	50.56
			average	16.91	1.68	12.60	31.22	18.09	13.95	1.42	11.61	26.97	15.25	15.52	1.53	11.56	28.61	16.6	86.80	49.48
			urea	14.00	1.57	15.87	31.44	18.24	12.37	1.49	14.82	28.67	16.63	13.07	1.49	12.93	27.48	15.93	87.58	49.93
T$_2$	2	3	UF	15.86	1.53	17.27	34.66	20.10	12.67	1.51	15.28	29.46	17.09	13.77	1.53	13.09	28.38	16.46	87.58	49.93
			average	14.93	1.55	16.47	32.95	19.17	12.52	1.50	15.05	29.06	16.88	13.42	1.51	13.01	27.93	16.20	89.93	51.27
			urea			23.33	23.33	13.53			18.74	18.73	10.86			16.24	16.24	9.42	58.30	33.23
T$_3$	0.0	4	UF			24.27	24.27	14.08			19.60	19.60	11.37			16.66	16.66	9.66	60.52	34.50
			average			23.8	23.80	13.80			19.17	19.16	11.11			16.45	16.45	9.54	59.41	33.86
			urea	20.53	1.72		22.25	12.91	14.93	1.55		16.48	9.56	15.17	1.50		16.66	9.66	55.39	31.57
T$_4$	2	0.0.	UF	21.93	1.82		23.75	13.78	16.10	1.57		17.67	10.25	15.87	1.56		17.42	10.10	58.82	33.53
			average	21.23	1.77		23.00	13.34	15.52	1.56		17.00	9.90	15.52	1.53		17.04	9.88	57.04	32.51
Average of seasonal biomass-C						16.10					13.29					13.06			41.78	
Averaged biomass-C of intercrops						18.63					16.07					16.4			50.37	
Averaged biomass-C of sole crops						13.57					10.51					9.71			33.19	
Biomass-C relative increase % for intercrops to sole crops						37.29					52.90					68.88			51.77	
Averaged biomass-C of UF						16.66					13.63					13.28			42.13	
Averaged biomass-C of urea						15.54					12.93					12.82			40.56	
Biomass-C relative increase % for UF to urea						7.23%					5.46%					3.59			3.86	
			A	1.99	0.03	1.65	0.33	0.16	0.96	0.02	0.62	0.21	0.16	2.91	0.02	1.88	10.24	0.17	0.18	0.27
L S D at 0.05			B	1.74	N.S	N.S	0.20	0.13	2.16	0.10	1.66	0.14	0.18	N.S	0.07	N.S	N.S	0.13	0.14	0.20
			AX B	N.S	N.S	N.S	0.38	0.24	N.S	N.S	N.S	0.2	0.35	N.S	N.S	N.S	N.S	0.24	0.27	0.39

Biomass-C. means the carbon absorbed from atmospheric CO$_2$ through photosynthesis and stored inside the plant
Biomass-C, ton fed^{-1} = crop, ton fed^{-1} x 0.58

Table (4): Effect of wheat / peas intercropping system and nitrogen fertilizer types on crop yield and biomass-C during the cultivated winter seasons of 3 years (2010-2011, 2011-2012 and 2012-2013)

Treatments				Yield (ton fed^{-1})												Total yield ton fed^{-1}	
				fourth season ,2010-2011				fifth season ,2011-2012				sixth season ,2012 -2013					
Inter cropping system (A)						Total yield				Total yield				Total yield			
Symbol	wheat row	Peas row	N. type (B)	Wheat	Peas	crop	biomass-C	Wheat	Peas	crop	biomass-C	Wheat	Peas	crop	biomass-C	crop	biomass-C
			urea	5.32	0.54	5.86	3.39	5.20	0.53	5.73	3.32	5.45	0.47	5.92	3.43	17.50	9.98
T$_1$	3	2	UF	6.11	0.59	6.69	3.88	5.77	0.54	6.31	3.66	5.84	0.90	6.34	3.67	19.34	11.02
			average	5.72	0.56	6.28	3.64	5.48	0.53	6.02	3.49	5.64	0.48	6.32	3.55	18.62	10.62
			urea	6.41	0.52	6.93	4.02	6.33	0.46	6.79	3.94	6.73	0.50	7.23	4.19	20.94	11.94
T$_2$	5	2	UF	7.47	0.56	8.03	4.66	6.80	0.51	7.31	4.24	6.87	0.54	7.41	4.30	22.75	12.97
			average	6.94	0.55	7.49	4.34	6.57	0.48	7.05	4.09	6.80	0.52	7.32	4.25	21.85	12.47
			urea		0.92	0.92	0.54		0.96	0.96	0.56		0.96	0.96	0.56	2.86	1.62
T$_3$	0.0.	2	UF		0.97	0.97	0.55		0.98	0.98	0.57		0.98	0.98	0.57	2.94	1.67
			average		0.95	0.95	0.54		0.97	0.97	0.57		0.97	0.97	0.57	2.89	1.65
			urea	7.72		7.72	4.48	7.60		7.60	4.41	8.13		8.13	4.72	23.45	13.37
T$_4$	6	0.0	UF	8.40		8.40	4.87	8.00		8.00	4.64	8.52		8.52	4.94	24.92	14.20
			average	8.06		8.06	4.68	7.80		7.80	4.53	8.33		8.33	4.83	24.19	13.79
Average of seasonal biomass-C						3.30				3.17				3.3		9.63	
Averaged biomass-C of intercrops						3.99				3.79				3.9		11.53	
Averaged biomass-C of sole crops						2.61				2.55				2.7		7.72	
biomass-C relative increase % for intercrops to sole crops						52.99%				48.62%				44.45		49.38	
Averaged biomass-C of urea						3.11				3.06				3.23		9.23	
Averaged biomass-C of UF						3.49				3.28				3.37		9.97	
biomass-C relative increase % for UF to urea						12.2 %				7.20 %				4.50 %		8.05%	
			A	0.36	0.05	0.66	1.26	0.39	0.024	0.96	1.29	0.31	0.02	0.77	1.03	0.31	0.66
L S D at 0.05			B	0.26	0.02	0.71	0.44	0.27	NS	0.37	0.38	0.09	0.019	0.14	0.12	0.009	0.06
			AX B	NS	NS	1.34	0.84	NS	NS	0.70	0.72	NS	NS	0.26	0.23	0.01	0.11

Biomass-C. means the carbon absorbed from atmospheric CO$_2$ through photosynthesis and stored inside the plant
Biomass-C, ton fed^{-1} = crop yield, ton fed^{-1} x 0.58

Regarding the effect of UF & urea fertilizer treatments, data show superiority for UF fertilizer to urea fertilizer as for averaged values of OM % change particularly in sole crop patterns. in logical consequence, the cumulative C% values have taken the same direction. Generally, the final averaged value of UF treatments has amounted 0.340 % for the former and 0.199% for the latter while they have amounted 0.27 % and 0.157 % for the urea treatments. Data also show mostly superiority for UF to urea in ensuring and sequestering carbon in soil where that the averaged SC values have ranged from 1.039 to1.880 ton Cfed^{-1} for UF and from 0.601 to 1.240 ton C fed^{-1} for urea (sum SC values for 3 successive layers) .corresponding averaged values of SCO$_2$ have ranged from 3.845 to 6.974 ton CO$_2$fed^{-1} for UF and from 2.224 to 4.582 CO$_2$fed^{-1} for urea. SC relative increase for UF to urea has amounted 44.074 %. It is noticed that most SC has been concentrated in top soil of urea treatments where SC% values ranged from 47.905 to 65.935% calculated as percentage of total SC of the three successive layers (0-10,10-30 and 30-60 cm) whereas these values for UF treatments have been distributed on different depths without certain trend as shown in the Table. It may be explained the distinguished impact of UF on SC comparing to that of urea on the basis of:1- the available nitrogen referred to UF fertilizer is surly less than that of urea fertilizer due to slowness its nitrogen release.2- It is well-known that nitrogen abundance in soil solution would result in stimulation of microorganisms propagation which promote the oxidized-decomposition of soil organic matter to obtaining energy for life. This findings is consistent with reports of SOC decline influenced by addition of conventional nitrogen fertilizers (Varvel, 1994, 2006; Pikul *et al.*, 2001; Olson *et al.*, 2005; Fierer *et al.*, 2003; Mack *et al.*, 2004).

Table(5):Sunflower /cowpea intercrops yield expressing in carbon form, emitted carbon dioxide form , emitted carbon form ,crop sequestered -carbon for every summer season and total soil emitted-carbon &total crop sequestered-carbon for the 3 summer growth seasons in Tonfed^{-1}

SYMBOl	Treatments			Yield , Ton fed^{-1}												Total C,Ton fed^{-1}	
	Inter cropping system (A)			2010				2011				2012					
	Sunflower row	Cowpea row	N. Form (B)	sunflower-cowpea carbon	Emitted CO_2 from soil	Emitted carbon from soil	Sequestered carbon	sunflower-cowpea carbon	Emitted CO_2 from soil	Emitted carbon from soil	Sequestered carbon	sunflower-cowpea carbon	Emitted CO_2 from soil	Emitted carbon from soil	Sequestered carbon	Emitted carbon from soil	Sequestered carbon
T_1			urea	17.18	5.42	1.46	15.71	14.40	4.49	1.22	13.18	15.99	4.55	1.22	14.76	3.90	43.65
	2	2	UF	18.39	4.20	1.13	17.25	15.56	3.00	0.811	14.74	16.62	3.37	0.91	15.70	2.86	47.69
			average	17.79	4.81	1.30	16.48	15.38	3.75	1.02	13.96	16.30	3.95	1.06	15.23	3.38	45.67
T_2			urea	17.92	5.08	1.37	16.55	16.35	4.29	1.16	15.19	15.66	4.81	1.29	14.36	3.82	46.09
	2	3	UF	19.76	4.60	1.24	18.51	16.79	3.58	0.97	15.83	16.18	3.37	0.91	15.26	3.12	49.59
			average	18.78	4.84	1.31	17.53	16.56	3.93	1.06	15.51	15.92	2.04	1.10	14.81	3.47	47.85
			urea	13.30	5.89	1.59	11.71	10.68	4.38	1.18	9.49	9.26	4.64	1.25	8.03	4.02	29.23
T_3	0.0	4	UF	13.83	4.41	1.19	12.64	11.17	3.91	1.05	10.12	9.49	3.72	1.01	8.49	3.25	31.25
			average	13.57	5.15	1.39	12.18	10.92	4.15	1.12	9.81	9.38	4.18	1.14	8.24	3.64	30.24
			urea	12.68	5.89	1.59	11.09	9.39	4.42	1.19	8.20	9.49	4.46	1.21	8.29	3.99	27.58
T_4	2	0.0	UF	13.54	4.08	1.10	12.43	10.07	4.70	1.27	8.80	9.93	3.35	0.90	9.03	3.27	30.27
			average	13.11	4.99	1.35	11.76	9.74	4.56	1.23	8.50	9.72	3.91	1.05	8.66	3.63	28.92
average of Urea				15.27	5.58	1.51	13.76	12.70	4.39	1.19	11.52	12.60	4.74	1.25	11.35	3.93	36.64
Average of UF				16.38	4.32	1.17	15.21	13.40	3.80	1.03	12.37	13.06	4.04	0.93	12.12	3.12	39.70
% sequestered-C relative increase for UF to urea				10.51				7.42				6.78				8.35	
Averaged sequestered-C of intercrops				17.01				14.74				15.02				46.76	
Averaged sequestered-C of sole crops				11.97				9.15				8.45				29.58	
% sequestered-C relative increase for intercrops to sole crops				42.06				60.99				77.75				58.06	
L S D at 0.05			A	2.26	0.17	0.28	0.11	0.58	0.01	0.13	0.37	0.14	0.32	0.37	0.29	0.11	1.04
			B	0.18	0.12	0.20	0.08	0.41	0.009	0.08	0.24	0.09	0.21	0.24	0.20	0.08	0.68
			AX B	0.34	0.23	0.38	0.15	0.77	0.01	0.16	0.46	0.18	0.41	0.46	0.38	0.16	1.29

Emitted carbon= Emitted CO_2x0.27

Crop sequestered carbon, ton fed^{-1}= sunflower-cowpea intercrops yield as a carbon tonfed^{-1}- soil emitted carbon, tonfed^{-1}

Table (6):Wheat-peas intercrops yield expressing in carbon form, soil emitted carbon dioxide form, soil emitted carbon form ,crop sequestered- carbon for every winter season and total soil emitted-carbon &total crop sequestered carbon for the 3 winter growth seasons in Tonfed^{-1}

Symbol	Treatments			Yield, Ton fed^{-1}												Total, Ton fed^{-1}	
	Inter cropping system (A)			2010-2011				2011-2012				2012-2013					
	wheat row	Peas row	N. Form (B)	Wheat -Peas carbon	Emitted CO_2 from soil	Emitted Carbon from soil	Sequestered carbon	Wheat-Peas carbon	Emitted CO_2 from soil	Emitted carbon from soil	Sequestered carbon	Wheat-Peas carbon	Emitted CO_2 from soil	Emitted carbon from soil	Sequestered carbon	Emitted carbon from soil	Sequestered carbon
T_1			urea	3.35	3.89	1.05	2.29	3.26	4.22	1.14	2.12	3.37	5.23	1.41	1.96	3.60	6.38
	3	2	UF	3.82	2.95	0.79	3.02	3.59	3.75	1.01	2.58	3.61	4.80	1.29	2.31	3.10	7.91
			average	3.58	3.43	0.92	2.66	3.43	3.98	1.08	2.35	3.60	5.02	1.35	2.14	3.35	7.15
T_2			urea	3.95	4.04	1.09	2.86	3.87	4.26	1.15	2.72	4.12	5.41	1.46	2.66	3.70	8.23
	5	2	UF	4.58	3.24	0.87	3.706	4.16	3.67	0.99	3.17	4.23	5.22	1.41	2.82	3.27	9.69
			average	4.26	3.64	0.98	3.28	4.02	3.97	1.25	2.94	4.17	5.32	1.43	2.74	3.49	8.97
			urea	0.53	4.31	1.16	- 0.63	0.54	4.18	1.13	- 0.59	0.55	5.73	1.55	- 0.99	3.84	-2.22
T_3	0.0	2	UF	0.55	3.31	0.89	- 0.34	0.56	3.08	0.83	- 0.27	0.56	5.35	1.44	- 0.88	3.17	-1.49
			average	0.54	3.81	1.03	- 0.49	0.55	3.63	0.98	-0.43	0.55	5.54	1.49	- 0.95	3.50	-1.86
			urea	4.40	3.66	0.99	3.41	4.33	4.04	1.09	3.24	4.63	5.34	1.44	3.19	3.52	9.84
T_4	6	0.0	UF	4.79	3.17	0.85	3.94	4.56	3.44	0.93	3.63	4.86	4.85	1.31	3.55	3.08	11.12
			average	4.59	3.41	0.92	3.67	4.45	3.74	1.01	3.44	4.75	5.09	1.38	3.37	3.30	10.48
Average of urea				3.06	3.98	1.07	1.98	3.0	4.17	1.13	1.87	3.17	5.43	1.47	1.70	3.66	5.56
Average of UF				3.44	3.17	0.85	2.58	3.2 2	3.48	0.94	2.28	3.32	5.05	1.36	1.95	3.16	6.81
% sequestered-C relative increase for UF to urea				30.05				21.57				14.60				22.45	
Averaged sequestered-C of intercrops				2.97				2.65				2.45				8.06	
Averaged sequestered-C of sole crops				3.19				3.01				2.43				8.62	
% sequestered-C relative increase for intercrops to sole crops				-6.72				-12.01				0.46				-6.55	
L S D at 0.05			A	0.68	NS	NS	1.16	0.52	NS	NS	1.02	0.11	NS	NS	1.11	0.06	0.02
			B	0.21	NS	NS	0.17	0.37	NS	NS	0.02	0.08	NS	NS	0.21	0.0.04	0.13
			AX B	0.41	NS	NS	0.33	0.70	NS	NS	0.38	0.16	NS	NS	0.41	0.08	0.25

Emitted carbon = Emitted CO_2x0.27

Crop sequestered-carbon, ton fed^{-1} = wheat-peas intercrops yield as a carbon, tonfed^{-1}

Table (7): N -rates of sunflower/cowpea and wheat/peas configurations for 1year & 3years, CO_2-C produced during N-fertilizer manufacture, CO_2-C emitted from soil and total CO_2-C for 3 years

treatment		N-rate for intercrops		N-rates		*CO_2-C from fert,		CO_2C from Soil , ton fed^{-1} For 3years		total CO_2C $tonfed^{-1}$ For 3years
		Intercrop 1 Sunflower /cowpea $KgNfed^{-1}$	Intercrop 2 Wheat /peas $KgNfed^{-1}$	$Kgfed^{-1}$ $year^{-1}$	$kgfed^{-1}$ for 3 year	CO_2-$Ctonfed^{-1}$ $year^{-1}$	CO_2-C $tonfed^{-1}$ For 3years	Intercrop 1	Intercrop 2	
T_1	urea	60	110	170	510	0.418	1.26	3.9	3.6	8.76
	UF	100	--	100	300	0.246	0.738	2.8	3.1	6.638
T_2	urea	60	110	170	510	0.418	1.26	3,82	3.7	8.78
	UF	100	--	100	300	0.246	0.738	3.12	3.27	7.128
T_3	urea	30	40	70	210	0.172	0.517	4.02	3.84	8.377
	UF	50	--	50	150	0.123	0.101	3.25	3.17	6.521
T_4	urea	30	70	100	300	0.246	0.738	3,99	3.52	8.248
	UF	50	--	50	150	0.123	0.369	3.27	3.08	6.719

*** CO_2-Ckg fed^{-1} = N-rate x 0.82**

Soil properties affecting carbon sequestration:

Among soil factors impacted SC are amount of soil organic matter (SOM), salinity, pH, N-fertilization, management practice and aeration. Therefore, the effects of studied different treatments on available-N, EC, pH and OM values will be here discussed. Fig.(9) shows the effect of urea and ureaform treatments on available-N, EC, pH and OM values (on average) measured at ending of every season (1,2,3,4,5 and 6).In general, the values of all above parameters have tended to increase with seasons progress (1to 6). Except OM, the effect of urea treatment on other parameters have been superior to that of UF, where the values of available-N, EC and pH have been slightly increased comparing to UF till the end of experiment .This effect has been expected and known for soluble nitrogen fertilizers and in harmony with the studies of Abbady *et al.*,(1999) and Ju *et al.*,(2007).The increased values of OM as affected by UF comparing to urea have been also expected and known, because the little amounts of nitrogen released from slow release fertilizer would not induce promotion of microorganisms and their enzymes ,and consequently, less breaking down for OM has been attended. Such effect has been agreed with findings of Martikainen(1989).

Fig. (10) and Fig. (11) illustrate the effect of sunflower/cowpea and wheat/peas intercropping configurations (treatments) on available-N, EC, pH and OM values, the general trend of this effect has been directed toward increasing along with seasons progress till the end of the experiment. Examination of the same figures , mostly show that T_1 and T_2 (intercrops) in each intercropping pattern have decreased the available nitrogen, EC and some extent, pH values but they have increased OM content comparing with T_3 and T_4 (sole crops) .In this respect, similar results have been obtained by Song *et al.*,(2007).

The results of averaged values of available nitrogen concentration remained in soil from urea &UF fertilizers after harvest and graphed against soil depth (Fig.12) show the general distribution of available-N for each which may be affected by permeability, porosity, irrigation and cropping systems ...etc. Also, they reveal that regardless of the fertilizer type , there is a gradual increase in nitrogen concentration from first season to six one. This increase has been higher in UF-N than that of urea-N, especially at top soil (0-10cm).This means that slow release nitrogen form has had resident time much longer than that of conventional one which has fast moved down soil profile with drainage water. The concentration of UF-N has been ranged from 58 to 96 mg kg^{-1} while such concentration for urea-N has been ranged from 53to 75 mg kg^{-1}, although the doses of UF-N has been added every tow growing seasons and such doses of urea-N added every one growing season. The concentration of UF-N has been decreased gradually with soil depth increase and collapsed to the half at the depth of 30-60 cm while the urea-N still as it is. Such behavior means that nitrogen fertilizer in slow release form has the ability to rest in top soil nearing to roots zone and vice versa in conventional nitrogen form. Here, it must be pointed out that from the ecological perspective, slow release nitrogen fertilizer may play an important role in conservation on soil profile and ground water from nitrate pollution (Alexander and Helm 2007 and Lu *et al.*, 2011) . In addition, its role in supporting carbon sequestration process as shown in foregoing results (Table.7 and Fig.9).

As regards soil physical properties influenced by the different treatments, Fig.(13)shows the effect of such treatments on averages of total wet stable aggregates %. With time progress of seasons under study, overall, it is observed that all studied treatments have increased wet stable aggregates %. However there has been some of preponderancy for UF fertilizer which has pronouncedly increased such aggregates comparing with urea as well as intercrops treatments (T_1andT_2) in both sunflower/cowpea &wheat/peas configurations which have given slightly higher values for such aggregates than those of sole crops (T_3 and T_4) which may due to more magnitude of roots for former than letter, where aggregation is promoted by root growth, their excrete compounds and surrounded microorganisms. From Fig.(14), it can be observed that the effect of the different treatments on macro-aggregates % has taken the same direction of total wet stable aggregates% (Fig. 13) and such effect has confirmed on significance of UF and intercrops treatments which has attained the opportunity to forming the aggregates with increase the OM from season to season, where organic carbon in soil tended to associate with fine particles like clay or silt as an organo-mineral association which would reflect upon the stabilization of organic carbon and consequently carbon sequestration process. Thus, aggregates physically protect soil carbon through formation of barriers between microbes & enzymes and its substrates (organic matter) ,thereby, they have controlled microbial turnover (Six *et al.*, 2002a and b). Fig.(15) shows the effect of studied different treatments on averages of bulk density (BD) measured at the end of every season, continuous decline for BD values of all treatments whether urea &UF or sunflower/ cowpea or wheat/peas intercrops configurations has been noticed with time passing by. It is also noticed that the decline related to UF fertilizer has been lower than that of urea as well as such lower decline has been mostly seen in both two configurations (T_1 andT_2) of the two intercrop patterns comparing with that of sole crops in each. This results have been expected, particularly, if it is retrieved the previous results of OM (Fig. 9,10 and 11) wet stable aggregates (Fig. 13) and macro-aggregates %(Fig.14) as influenced by the different treatments and agreed with the study of Hulugalle and Ezumah(1991). The trend of different treatments effect on total porosity (Fig .16) has been the same as the trend of their effects on wet stable aggregates% (Fig. 13) and macro-aggregates % (Fig.14).such picture has been expected because the magnitude of porosity is truly reflection for aggregation process as reported by Regelink *et al.*, (2015).

The correlation between OM % and water stable macro aggregates % has been generally low (Fig. 17) . In first, second and third seasons there have been no change in R^2 values. Then, they have been somewhat increased until the sixth season. Although marked gradual increase for macro aggregates initiated from first season till the sixth one as affected by different treatments (Fig.14), it seems that the correlation relationship may be negatively affected by distribution of OM within the soil matrix and its interaction with micro aggregates or the lack of OM, where its building up is very difficult and no OM source has been added in this experiment or the time necessitated to cement micro aggregates is not enough. Moreover, that macro aggregates may be controlled by soil management .macro aggregates initiated from first season till the sixth one as affected by different treatments (Fig.14), it seems that the correlation relationship may be negatively affected by distribution of OM within the soil matrix and its interaction with micro aggregates or the lack of OM, where its building up is very difficult and no OM source has been added in this experiment or the time necessitated to cement micro aggregates is not enough. Moreover, that macro aggregates may be controlled by soil management.

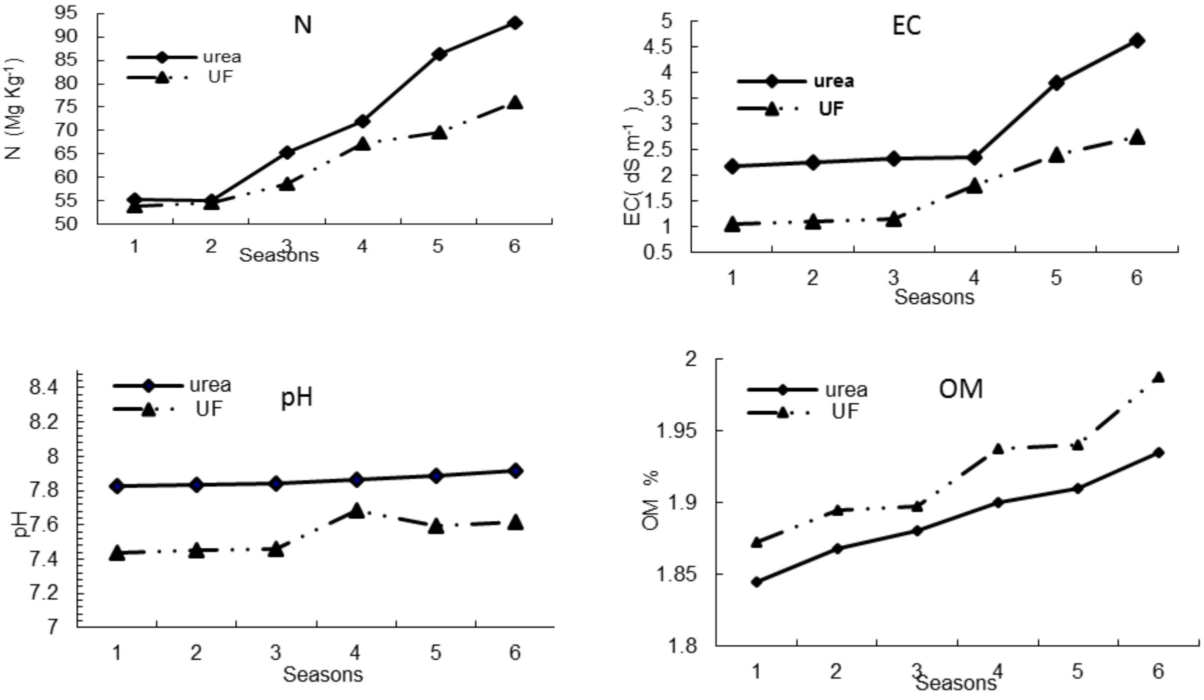


Fig. (9): Effect of urea and ureaform on available-N, EC, pH and OM

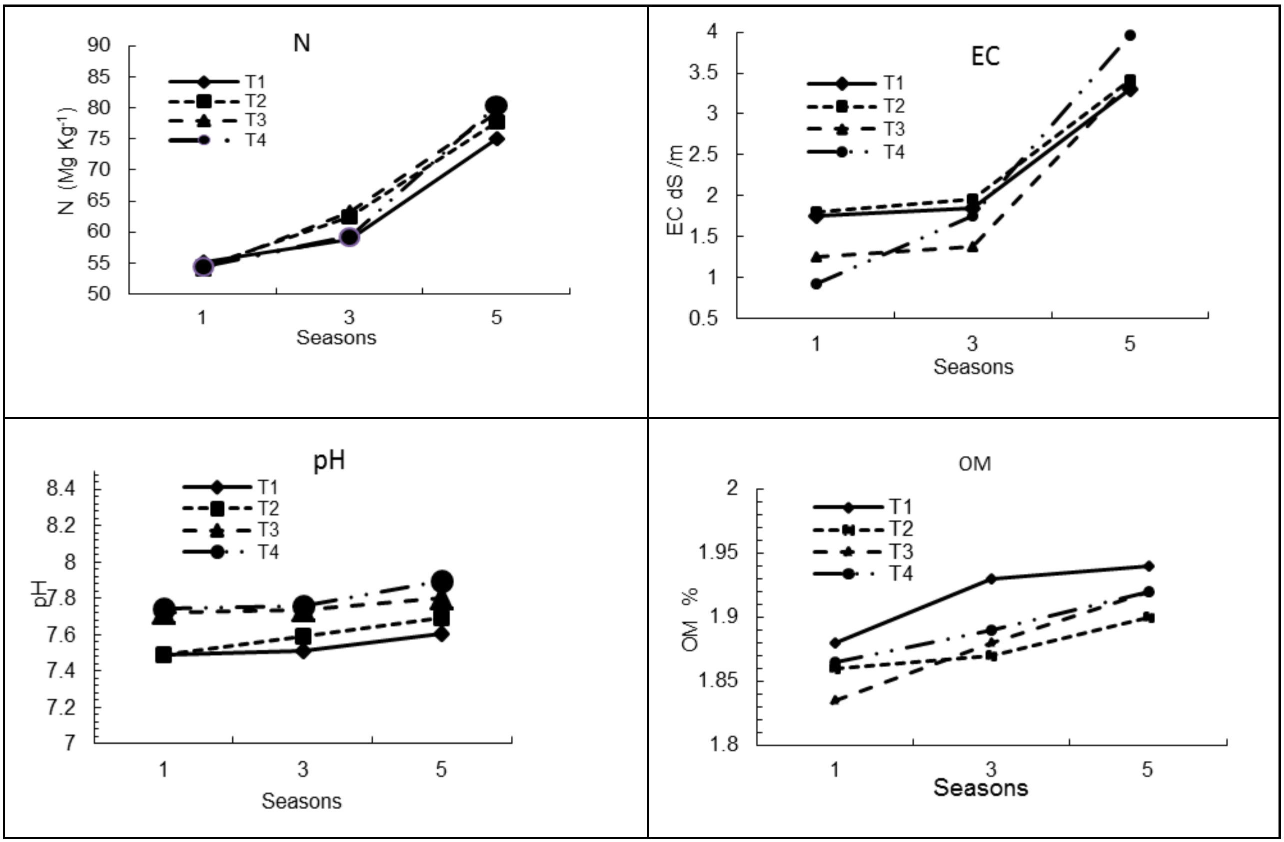


Fig. (10): Effect of sunflower/cowpea intercropping configurations on available-N, EC,pH and OM

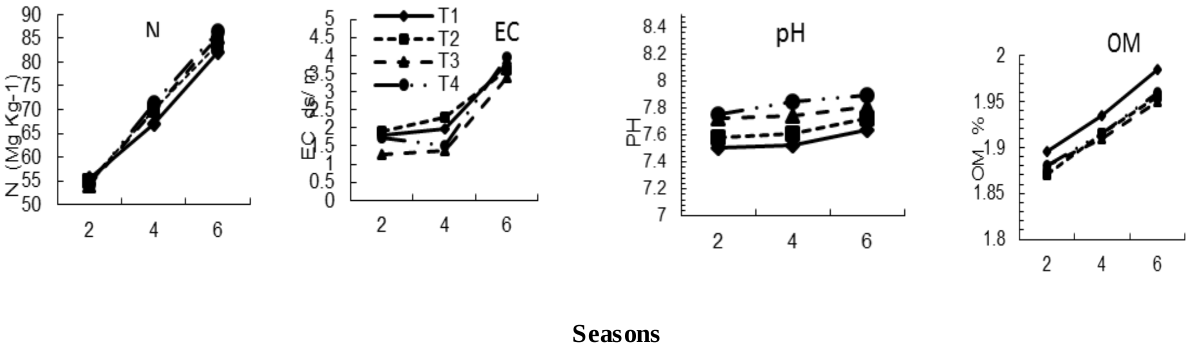


Fig. (11): Effect of wheat/peas intercrops configurations on available-N, EC, pH and OM

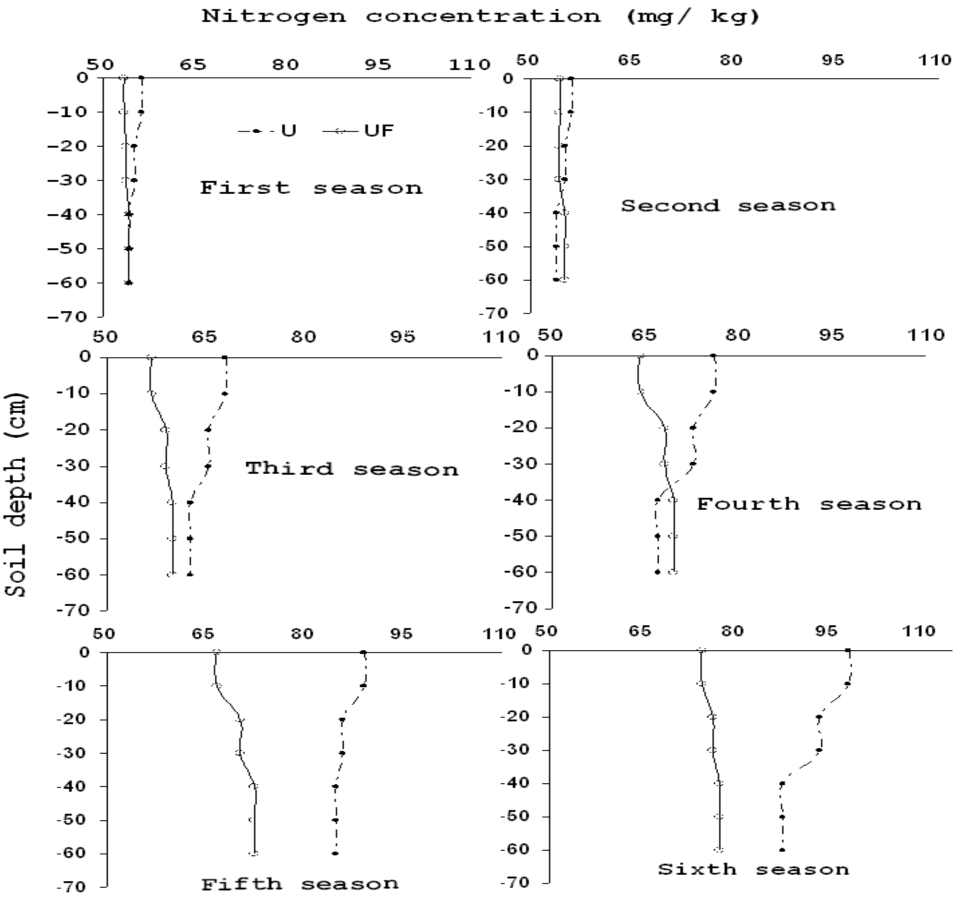


Fig. (12): Changes in available nitrogen levels of residual urea(U) and UF fertilizers estimated after harvest, down the soil profile (0-60 cm) for the six successive seasons

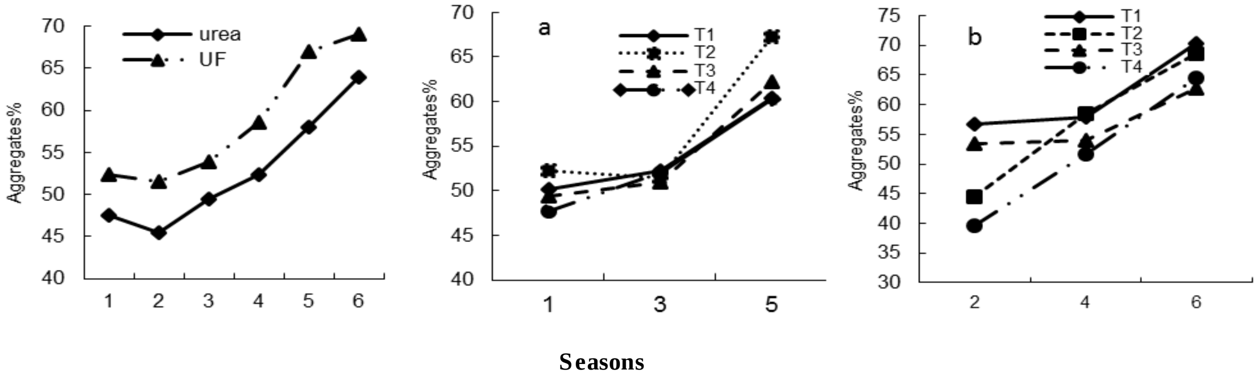


Fig. (13): Effect of urea & UF fertilizers, sunflower/cowpea (a) and wheat/peas (b) intercrops configurations on averages of total wet stable aggregates%.

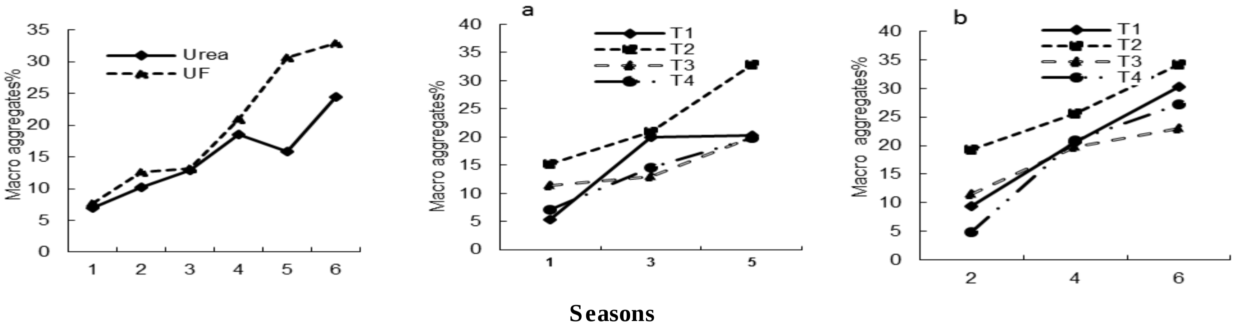


Fig. (14): Effect of urea &UF, sunflower/ cowpea (a) and wheat/peas (b) intercrops configurations on averages of macro aggregates

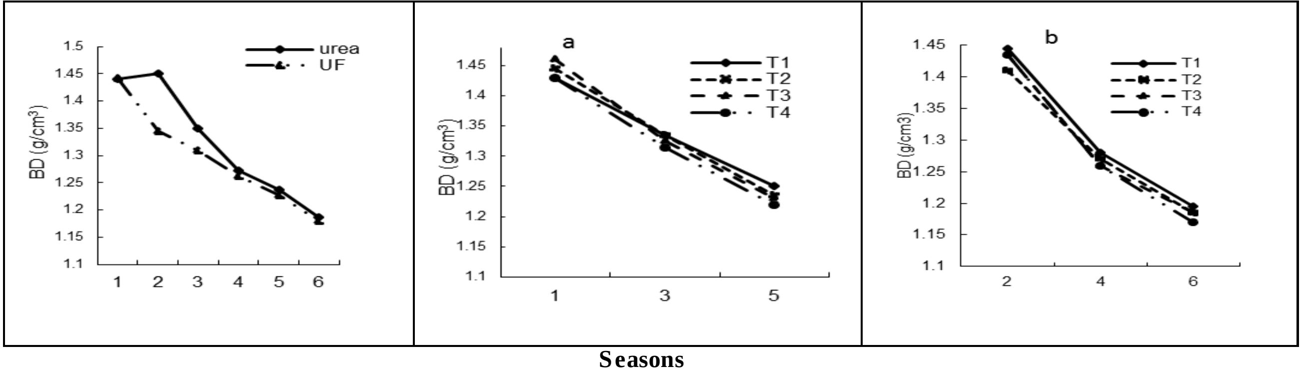


Fig.(15):Effect of urea& UF, sunflower/ cowpea(a) and wheat/peas (b) intercrops configurations on averages of BD

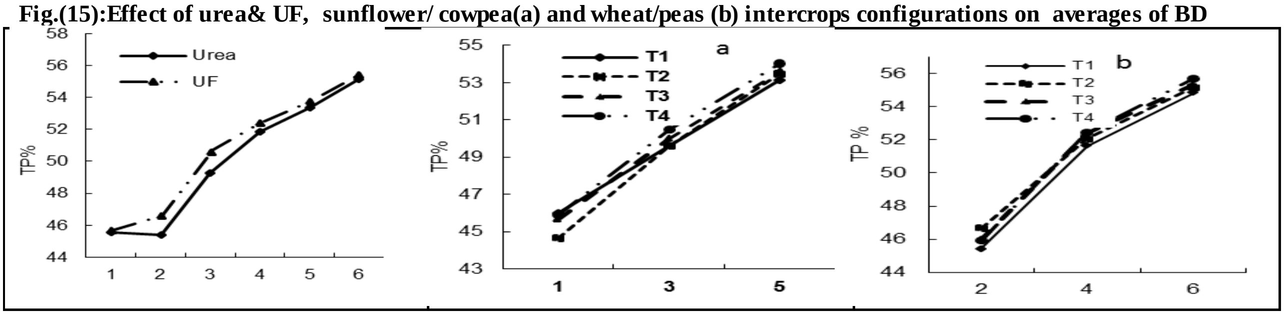


Fig.(16):Effect of urea &UF, sunflower/ cowpea(a) and wheat/peas (b) intercrops configurations on averages of TP%

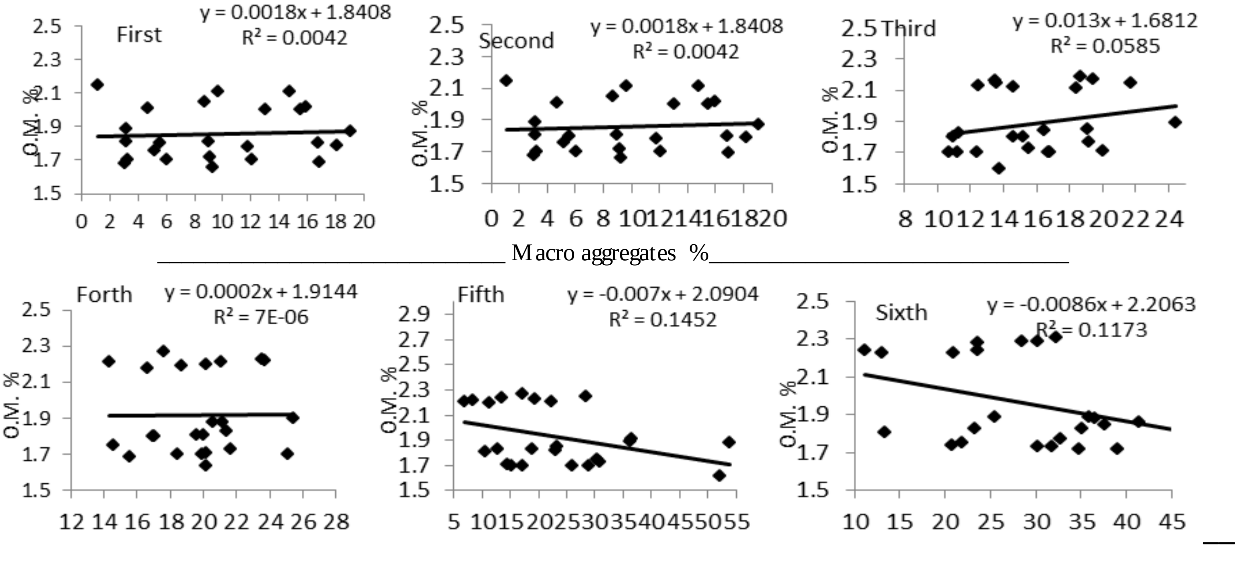


Fig. (17): Correlation between macro aggregates% and OM % at every season of the six seasons

Table (8): Changes in OM %, cumulative C% and sequestered-carbon (SC) &its equivalent CO_2 (SCO_2) at the end of the experiment (6 seasons) as affected by different treatments

treatment		Depth (cm)	OM_1 (%)	OM_6 (%)	change in OM%	cumulative C%	SCton^{1}fed	SCO_2 ton^{1}fed	SC %
T_1	Urea	0-10	2.01	2.24	0.23	0.133	0.593	2.195	47.905
		10-30	1.78	1.83	0.05	0.029	0.258	0.955	20.842
		30-60	1.70	1.75	0.05	0.029	0.387	1.432	31.25
		sum	5.49	5.82	0.33	0.191	1.240	4.582	
	UF	0-10	2.15	2.29	0.14	0.081	0.361	1.336	26.36
		10-30	1.89	1.95	0.06	0.035	0.312	1.154	22.765
		30-60	1.76	1.85	0.09	0.052	0.697	2.579	50.878
		sum	5.8	6.09	0.29	0.168	1.368	5.069	
	Mean		5.645	5.955	0.31	0.189	1.304	4.826	
T_2	Urea	0-10	2.00	2.23	0.23	0.133	0.593	2.194	50.17
		10-30	1.79	1.86	0.07	0.041	0.362	1.339	30.62
		30-60	1.69	1.72	0.03	0.017	0.227	0.840	19.21
		sum	5.48	5.81	0.33	0.191	1.182	4.373	
	UF	0-10	2.11	2.31	0.2	0.116	0.517	1.913	49.753
		10-30	1.87	1.88	0.01	0.006	.0.054	0. 200	5.201
		30-60	1.66	1.72	0.06	0.035	0.468	1.732	45.045
		sum	5.64	5.91	0.27	0.157	1.039	3.845	
	Mean		5.56	5.86	0.30	0.174	1.111	4.11	
T_3	Urea	0-10	2.02	2.23	0.21	0.122	0.544	2.013	65.935
		10-30	1.80	1.81	0.01	0.006	0.054	0.200	6.551
		30-60	1.70	1.73	0.03	0.017	0.227	0.840	27.51
		sum	5.52	5.77	0.25	0.145	0.824	3.053	
	UF	0-10	2.00	2.28	0.28	0.162	0.722	2.671	38.299
		10-30	1.80	1.89	0.09	0.052	0.463	1.731	24.820
		30-60	1.68	1.77	0.09	0.052	0.695	2.572	36.88
		sum	5.48	5.94	0.46	0.267	1.880	6.974	
	Mean		5.5	5.855	0.36	0.206	1.352	5.013	
T_4	Urea	0-10	2.11	2.24	0.13	0.075	0.334	1.236	55.576
		10-30	1.81	1.83	0.02	0.012	0.107	0.386	17.356
		30-60	1.72	1.74	0.02	0.012	0.160	0.592	26.619
		sum	5.64	5.81	0.17	0.099	0.601	2.224	
	UF	0-10	2.05	2.29	0.24	0.139	0.620	2.294	48.965
		10-30	1.81	1.89	0.08	0.046	0.410	1.517	32.38
		30-60	1.70	1.73	0.03	0.017	0.227	0.840	17.93
		sum	5.56	5.91	0.35	0.203	1.257	4.685	
Mean			5.6	5.86	0.26	0.151	0.929	3.438	
Mean of urea			5.533	5.803	0.27	0.157	0.962	3.559	
Mean of UF			5.62	5.963	0.340	0.199	1.386	5.128	
sequestered-C relative increase % for UF to urea						44.074			
Averaged sequestered-C of intercrops						1.208			
Averaged sequestered-C of sole crops						1.141			
sequestered-C relative increase % for intercrops to sole crops						5.83			

Change in OM% = OM_6 % - OM_1 %
OM_6 is OM analysis after the end of growing season 6
OM_1 is OM analysis after the end of growing season 1
cumulative C% = (OM_6 % - OM_1 %) x 0.58
SC, tonfed^{-1} = fed. area (m^2) x layer depth (m) x OC % x BD (Mg/m^3) CO_2 = C x 3.7

In conclusion, it seems that the intercropping system and slow release N-fertilizer could positively contribute to increase crop yield and other multiple agro-ecosystem services; the interaction among the different studied elements of this experiment has facilitated opportunity for the soil chemical, physical and biological processes to achieve their important role in improving soil properties and consequently, resulted in these positive promised implications and finely indeed ensured and sequestered organic carbon. Thus, agriculture soil could be useful instrumental in formulating efficient strategies related to carbon sequestration and reduction of CO_2 emissions.

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حفظ الكربون كدالة لممارسة الأدارة الزراعية بالتداخل المحصولى وانواع مختلفة من الأسمدة النيتروجينية

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*** معهد بحوث الأراضى و المياه و البيئة**

**** معهد بحوث المحاصيل الحقلية**

أُقيمت تجربة بمحطة البحوث الزراعية بالجيزة. مركز البحوث الزراعية، استمرت لمدة ٣ سنوات(٢٠١٠-٢٠١٣)لاختبارتأثيرزراعة نموذجين من التعاقب المحصولى المنفذين بنظام التداخل المحصولى وكذلك التسميد النيتروجينى على حفظ الكربون فى كل من الكتلة المحصوليه والتربة وكذلك تأثير هذه الإدارة على انبعاث ثانى اكسد الكربون من التربة .أيضا أُخذ فى الأعتبار قياس تأثيرالتغير فى درجة الحرارة والرطوبة على تلك الانبعاثات.بهدف اختبارقدرة هذه النوعية من الادارة الزراعية على تخفيف حدة الاحتباس الحرارى الناتج من زيادة تركيز ثانى اكسد الكربون فى الغلاف الجوى و بالتالى تخفيف حدة التغيرات المناخية. النموذج الأول(التداخل المحصولى الأول) كان عباد شمس/لوبياالعلف ورتب كالآتى:٢/٢،٢/٣ خط،،عباد شمس منفرد و لوبيا علف منفرد.النموذج الثانى (التداخل المحصولى الثانى) كان قمح/ بسلة ورتب كالآتى: ٢/٣، ٢/٥خط ، بسلة منفردة وقمح منفرد. للتسميد النيتروجينى: أستخدمت اليوريا كسماد نيتروجينى تقليدي و اليوريافورم كسماد بطئ الذوبان. كانت المعدلات من اليوريا كالآتى:.٦٠،٦٠، ٣٠ ، ٣٠ كجم نيتروجين/فدان لكل معاملة من معاملات التداخل الأول بينما بلغت١١٠ ، ١١٠،٤٠، ٧٠ كجم نيتروجين/فدان لكل من معاملات التداخل الثانى والتى كانت تضاف دوريا كل موسم زراعى.كانت المعدلات من اليوريافورم كالآتى:٥٠،٥٠،١٠٠،١٠٠ كجم نيتروجين/فدان لكل من معاملات التداخل الأول وبنفس الترتيب والتى كانت تضاف دوريا كل٢ موسم زراعى.آى أنه لم يضف اى سماد نيتروجينى لمعاملات التداخل الثانى واعتمدت فى نموها على المتبقى من نيتروجين اليوريافورم المضاف فى الموسم الاول وهكذا حتى نهاية التجربة.توزعت هذه المعاملات باستخدام تصميم القطع المنشقة وكانت معاملات التداخل المحصولى هى القطع الرئيسية ومعاملات الأسمدة هى القطع الشقية. بالإضافة إلى ذلك الحقت معاملتين بدون زراعة لقياس ثانى اكسيد الكربون المنبعث تحت الظروف الجافة والمروية. قيست انبعاثات ثانى اكسيد الكربون من التربة اسبوعيا باستخدام تكنيك الحجرة الثابتة وكان يقدر بالتفاعل مع هيدروكسيد الصوديم ثم بالتعادل الرجعى باستخدام حمض الهيدروكلوريك.فى تلك الاثناء سجلت درجات الحرارة تحت المعاملات المختلفة. واخذت عينات من التربة لتقدير المحتوي الرطوبى.أيضا اخذت عينات من التربة لتقدير بعض الخواص الطبيعيه و الكيميائية بعد كل موسم حصاد(٦ موسم). بعد مرور ٣ سنوات متعاقبة من تبادل زراعة التداخلين المحصوليين المذكورين سابقا. أشارت النتائج إلى: أنه تحت ظروف هذه التجربه،تراوحت قيم التغير فى د رجات الحرارة بين١٢ و٤٥ درجة مئوية كما تراوحت قيم المحتوي الرطوبى بين ٢ و٥٥ %.و ذلك على عمق ٥سم من سطح التربة.إحصائيا لوحظ عدم وجود إرتباط أو إرتباط ضعيف بينهم وبين ثانى أكسيد الكربون المنبعث من التربة. كميات ثانى أكسيد الكربون المنبعث من التربة فى فصول الصيف و المقدر فى القطع المروية كانت أعلى من تلك المنبعثة من القطع الجافة والمقدرة فى فصول الشتاء.معاملات المحاصيل المتداخلة وسماد اليوريافورم(بطئ الذوبان) أسهما فى الحصول على أقل مستوى من الإنبعاثات مقارنة بمعاملات المحاصيل المنفردة و تلك المسمدة باليوريا. معاملات المحاصيل المتداخلة وتلك المسمدة باليوريافورم غالباً أعطت غلة محصولية أعلى من تلك الناتجة من معاملات المحاصيل المنفردة ومن تلك المسمدة باليوريا.وجد ايضا أن معاملات المحاصيل المتداخلة وتلك المسمدة باليوريافورم اكثر كفاءة فى حفظ الكربون من معاملات المحاصيل المنفردة وتلك المسمدة باليوريا سواء فى الكتلة المحصولية أو فى التربة.تراوحت الزيادة النسبية للمحاصيل المتداخلة بالنسبة للمحاصيل المنفردة فى حفظ الكربون فى الكتلة المحصولية بين 42.06و٧٥. ٧٧% للتداخل المحصولى عباد شمس /لوبيا علف و بين٠١. ١٢-و ٤٦. ٠ % للتداخل المحصولى قمح/ بسلة.كما تراوحت الزيادة النسبية لليوريافورم بالنسبة لليوريا فى حفظ الكربون فى الكتلة المحصولية تحت معاملات التداخل الأول بين ٧٨. ٦ و ٥١. ١٠%بينما كانت ١٤.٦٠ و٣٠ % للتداخل الثانى. بعد ٣سنوات من إجراء التجربة، بلغت الزيادة النسبيةفى حفظ الكربون الأرضى للمحاصيل المتداخلة بالنسبة للمحاصيل المنفردة ٥.٨٣%.كما بلغت تلك الزيادة لليوريافورم بالنسبة لليوريا ٤٧ %. كما لوحظ ان التحسن المتدرج الملحوظ فى محتوى المادة العضويه و الأملاح الكلية والأس الأيدروجيني و النيتروجين الميسر و التجمعات الثابتة و المسامية إنعكس ايجابيا على حفظ الكربون فى التربة.