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Effect of aerobic rice planting methods on methane emission, water fingerprint and rice productivity under different sources of organic fertilizer

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ABSTRACT

Flooded rice is a source of atmospheric methane (CH4) which is one of the greenhouse gases caused global warming flooded rice also, consumed high amount of water despite its rare in Egypt. This study focuses on mitigation strategies to face those problems by testing organic fertilization under different cultivation methods, for rice varieties and their effect on CH4 flux and grain yield of rice. Two field trials were conducted at Sakha agriculture research station during 2021 and 2022 growing seasons, whereas the experiments were designed in split-split plot design with four replications. The main plot consisted of three planting methods; transplanting, furrow and drill. The sub plot involved two rice varieties namely, Giza 179 and Sakha supper300. The sup-sup plots were subjugated by organic fertilizer, rice straw compost, farm yard manure and filter mud compost as well as control treatment. The result of the study provides that rice cultivars are major causes of variations in CH_4 fluxes. Sakha super300 rice variety contributed in increasing CH4 gas emission than Giza179 variety. CH4 emission depends on the type of organic matter, applied rice straw compost and farmyard manure increased methane gas emission than filter mud compost. CH4 gas emission decreased under furrow and drill cultivation methods meanwhile, the defense system of rice plants increased compared with transplanting. Yield and its components increased under transplanting compared with other cultivation methods, yield increased by applied organic matter than control. Giza179variety was better than Sakha super300variety under dry cultivation and produced a higher grain yield. To sum up, furrow irrigated rice using Giza179 rice variety fertilized by filter mud compost can reduce methane gas emission and save water in addition to obtaining better grain yield.

Key words: Planting methods, defense system, CH4 emission, Organic matter, Rice

INTRODUCTION

Since the population globally is expected to increase, the rice cultivation areas globally must increase, so CH4 gas emission is expected to continue to increase in the near future (FAO, 2020). Methane is the second major greenhouse gas after CO2its more powerful than CO2 28 times and it caused raise global surface temperature (Aydin *et al.* 2010 and IPCC, 2021). Rising in the global temperature has an injurious effect on our lives, (Hoegh-Guldberg et al. 2018). According to (IPCC, 2013 and IPCC, 2021) rice paddies contribute over 11% of CH4 gas emissions from 53% all agricultural sector deliveries. Availability of methanogenic substrates and their impact on environmental factors are primarily determined by the quantity of methane formed in flooded rice soils. The plants root exudation, root senescence and plant litter are the sources of organic carbon which responsible for methanogenic substrates (Lu et al., 1999 Gu et al., 2022). Rice planted area in the world about 165.25 million hectares the CH4 emission from rice paddies depends on many factors including; water management (Wang *et al.,* 2018, Yusuf *et al.,* 2012 and Shahbandeh, 2023), soil properties as salinity and soil pH (Yan et al., 2009 and Shang et al.,2020), as well as application of organic matter in a different type (Feng *et al.,* 2013 and IPCC 2019), rice varieties (Qin *et al.,* 2015) and other factors (Banger *et al.,* 2012). Among these factors, cultivation method and organic matter application are closely related to CH4 efflux. Direct seeding of rice can contribute in solving water shortage and methane emission problems, it is a successful method in various rice growing countries of the world (Adair *et al.,* 1992). Bed planting methods induce higher water use efficiency especially in rice in Egypt where misery for water and suffering from salinity soil are critical factors (Zayed et al., 2012 and Zayed *et al.,* 2023). Furrow irrigated rice can save water about 50 to 60% also can reduce CH4 emissions, application of fertilizer and chemicals (Wilson *et al.,* 2006, Brooks *et al.,* 2010 and Zayed *et al.,* 2023). Transplanting cultivation method or flooded rice could be making an anaerobic condition within the soil by changing the oxygen statues from the atmosphere into the soil, anaerobic condition induce methanogens as methane producers motivate to be dynamic (Singh, 2009 and Cui, et al.,2018). Some microbial communities such as methanotrophic bacteria in the surface soil layer are responsible for methane oxidation before release into the atmosphere, the Activation of methanogens could be influenced by the irrigation system (Singh *et al.,* 2010 and Gu *et al.,* 2022). Organic fertilizers can ensure safe agricultural production without harming people, soil, and the environment due to its organic contents (Shang *et al.,* 2020 and Ferdous *et al.,* 2021). Organic fertilizer protects soil health in good condition by enhancing the supply of nitrogen and promoting microorganisms' growth. It also develops soil structure and increases soil fertility and water holding capacity by adding nitrogen that is very useful for crop production. The objectives of this study were to decrease methane gas emissions, save irrigation water, decide which type of organic fertilizer can achieve our strategies to face global climate change in saving water and reduce methane emission with high yield.

MATERIAL AND METHODS

Field trails were conducted at the Experimental Farm of Sakha Research Station, Agricultural Research Center, Kafr El-Sheikh, Egypt during 2021 and 2022 growing seasons. All experiments were preceded by a barley crop (Hordeum spp.). The results of mechanical and chemical soil properties are presented in **Table (1).**

Table 1. Mechanical and chemical analysis of the experiments soil

Soil analysis	**2021**	**2022**
Soil texture (%)	clayey	clayey
pH	8.05	8.25
ECe(dSm^{-1})	6.40	7.05
Organic matter %	0.90	0.87
Available NH_4 mg kg^{-1}	16.50	14.60
Available NO_3 mg kg^{-1}	13.80	12.00
Available P mg kg^{-1}	14.00	12.00
Available K mg kg^{-1}	300	280
Available Zn mg kg^{-1}	1.1	1.0

Table 2. Chemical composition of different organic material sources used in the experiment

Items	**Organic sources**		
	RSC	**FYM**	**Filter mud**
ECe(dSm^{-1})	3.67	4.01	3.52
pH	7.28	7.37	6.5
Organic matter %	41.3	42.1	43.8
Organic C%	34	33	36
Total N%	1.92	1.83	2.11
P%	0.75	0.77	0.81
K%	1.67	1.68	1.77
Water holding capacity	197.4	198	200.8
C\N ratio	17.7	18	17.14

Experimental Design and Land Preparation:

The experiment was laid out in a split-split plot design with four replications. The main plots consisted in three planting methods; transplanting, furrow and drill. The sub plot involved two rice varieties namely, Giza 179 and Sakha super300. The sup-sup plots were subjugated by organic fertilizer; rice straw compost, farm yard manure and filter mud compost as well as control (without organic fertilizer). Organic fertilizer was applied at the rate of 2.5t fed^{-1}for each. The culture practice and recommendation package corresponding to each planting method was applied according to RRTC, ARC and ministry of agriculture.

At the heading stage, plants of five hills were randomly taken from each plot to estimate dry matter production. Leaf of three hills were randomly taken to determine the leaf area of plant samples and they were measured by Portable Area Meter (Model LI– 3000A), then leaf area index (LAI) was estimated (Barclay *et al.,* 2000).

CH4 and CO2 concentrations:

CH4 and CO_2 concentrations in the gas samples were analyzed using a gas chromatograph equipped with a flame ionization detector (GC-8A, Shimadzu Corporation, Kyoto, Japan) (Naser *et al.* 2007).

Determination of chlorophyll fluorescence. chlorophyll fluorescence was measured using a portable fluorometer (Handy PEA, Hansatech Instruments Ltd, Kings Lynn, UK). One leaf (at the same age) was chosen per plant to conduct the fluorescence measurements. Maximum quantum yield of PS II *Fv/Fm* was calculated using the formulae; *Fv/Fm= (Fm – F0) / Fm* (Maxwell and Johnson, 2000).

Rapid screening chlorophyll fluorometer:

Fm: maximal fluorescence, Fv: variable fluorescence, Fv/Fm:

Photosynthetic pigments contents of leaves:

Chlorophyll a, chlorophyll b, and carotenoids were measured from five disks which were taken from the rice takes off. The shades were extricated by pounding in 85%aqueous acetone (20 ml) and a squeeze of CaCO3 were included to the acetone arrangement some time recently pounding. After filtration the volume of acetone arrangement was total to 20 ml. The whole chlorophyll colors were decided by perusing the receptiveness on spectrophotometrically at 662, 644 and 470 nm and concentration of photosynthetic colors were calculated agreeing to the condition said by Lichtenthaler and Buschmann (2001).

Chl.a =11.24 (0.D) 662-2.04 (0.D)644= mg/L
Chl. b =20.13 (0.D) 644-4.19 (0.D)662= mg/L
Car. =1000 (0.D) 470- 1.90 chl.a -63.14 chl. b)/214= mg/L

Antioxidant enzyme activities:

Protein Assay kit (Model: Bio-Rad DC, California, USA) and bovine serum albumin as a standard were used to estimate the activity of Catalase CAT (EC 1.11.1.6), Peroxidase activity (POD) and super oxide dismutase (SOD)(EC 1.6.4.2). An amount of 0.5 g fresh sample was extracted according to the following method as described by Takagi and Yamada (2013). An aliquot of 1 ml of the CAT assay mixture was also used which was contained 50 mM potassium phosphate buffer (pH 7.0), 10 mM H2O2, and enzyme extract (5%). A decline in H2O2 was recorded at 240 nm to know the enzyme activity which is expressed as mmol H2O2 consumed per minute. 1 ml assay mixture containing 100 mM phosphate buffer (pH 7.5), 0.1 mM EDTA, 0.02 mM NADPH, 0.02 mM GSSG and 10% enzyme extract were used to know the GR activity. The concentration of oxidized NADPH was determined by using the extinction coefficient (6.22 mM^{-1} cm^{-1}) and 1-unit GR activity defined as µmol NADPH oxidized min-1. For the measurement of POD activity, 1 ml reaction mixture contained 15 m Mguaiacol, 73 mM phosphate buffer, 10 mM H2O2 and 2% enzyme extract. Increase in absorbance was monitored at 470 nm for 1 min and the enzyme activity calculated using the extinction coefficient (26.6 $mM^{-1}cm^{-1}$) for tetra guaiacol (Chance and Maehly, 1955). One-unit POD activity was defined as mmol tetra guaiacolbnpf; formed per min.

Water productivity (WP) was calculated as the weight of grains per unit of irrigation received during crop growth (kg grain / m^3 water input)

Water use efficiency (WUE) is generally defined in agronomy (Viets, 1962) as WUE = Crop yield (usually the economic yield)/ Water used to produce the yield

At harvest, plant height was estimated and total numbers of panicles per m^2 were counted. Ten random panicles were collected from each plot to estimate panicle length, number of filled grains/panicle, number of unfilled grains/panicle, panicle weight, and 1000-grain weight. Grain and biological yields were randomly measured and grain yield was adjusted to 14 % moisture content, and then the yield of the 9 m^2 was computed and transferred to tons per hectare.

Statistical Analysis:

According to Gomez and Gomez (1984) the data gathered were statistically analyzed using the analysis of variance technique. Duncan's Multiple Range Test was used to compare the treatment means (Duncan 1957). All statistical analyses were done using "COSTAT" statistical software package**,** Berkely (1988).

RESULTS

1-Methane gas emission:

The CH4 emission rates varied across different rice growth stages during the study seasons as shown **in figures1 and 2**. It's noticed that CH4 emission changes from low rate in early growth stages to a high rate in middle growth stages then decrease again with late growth stages. Transplanting as a planting method significantly increase CH4 emission rate compared with dry cultivation methods represented in furrow and drill rice., Moreover the CH4 emission rate decreased by furrow cultivation method compared with other tested cultivation methods in both seasons. CH4 emission rate varied for different rice genotypes Giza179 formed a lesser amount than Sakha super 300 in both seasons.

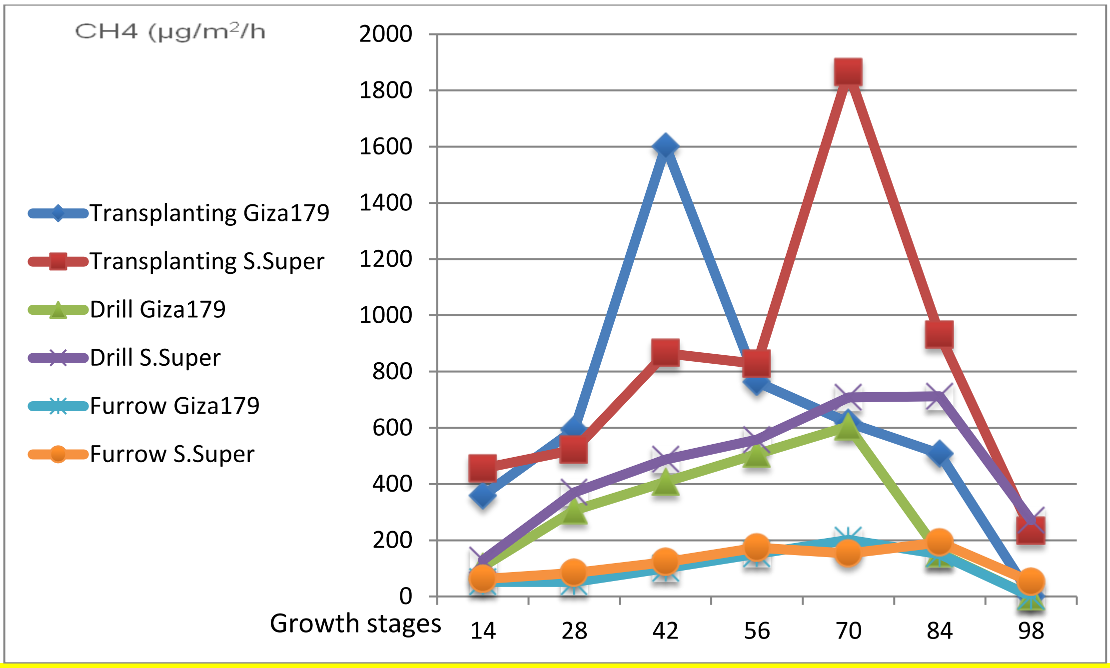

Fig. 1. Methane gas emission during different growth stages as affected by rice varieties and planting methods in 2021 season

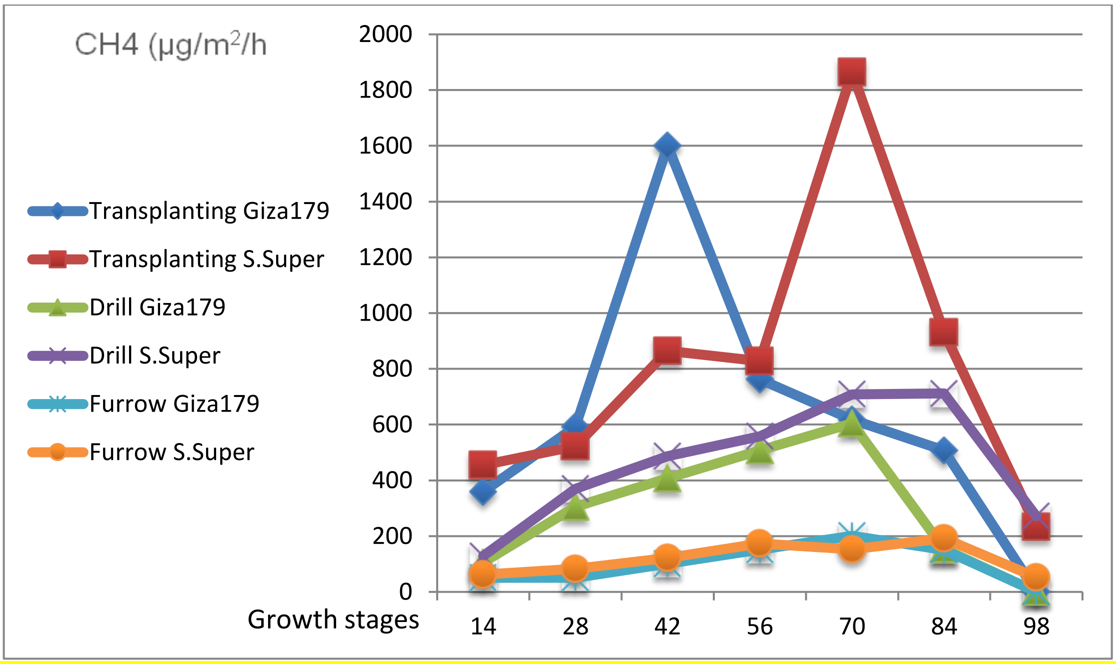

Fig. 2. Methane gas emission during different growth stages as affected by rice varieties and planting methods in 2022 season

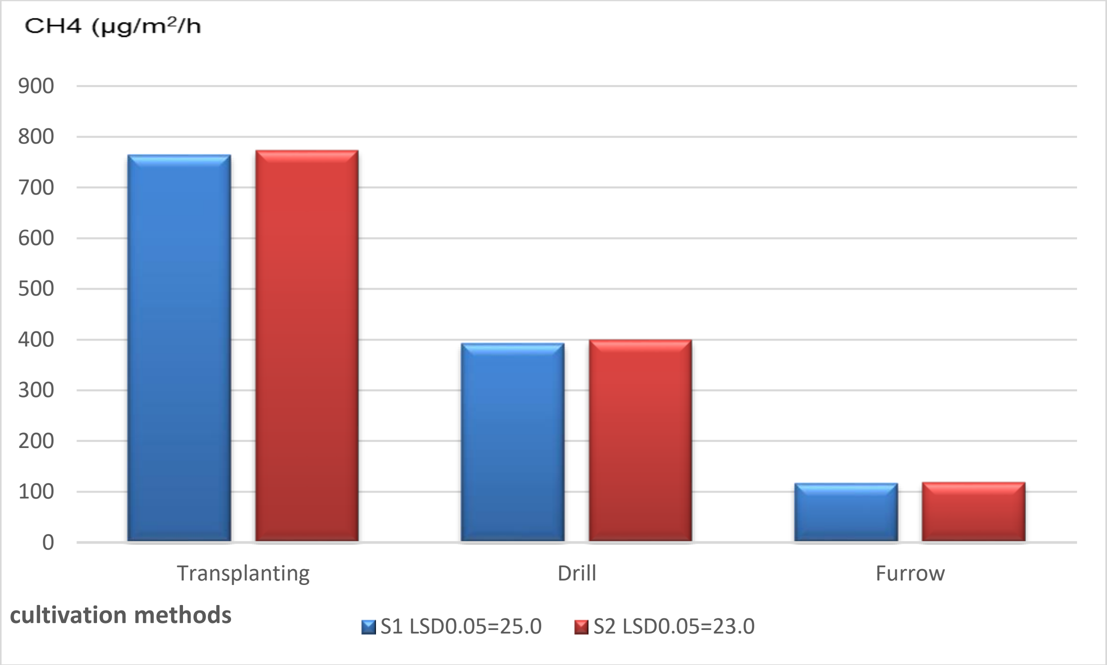

Fig. 3. Methane gas emission affected by planting methods in 2021and 2022 seasons

Fig. 3. S1=season2021 and S2 = season2022

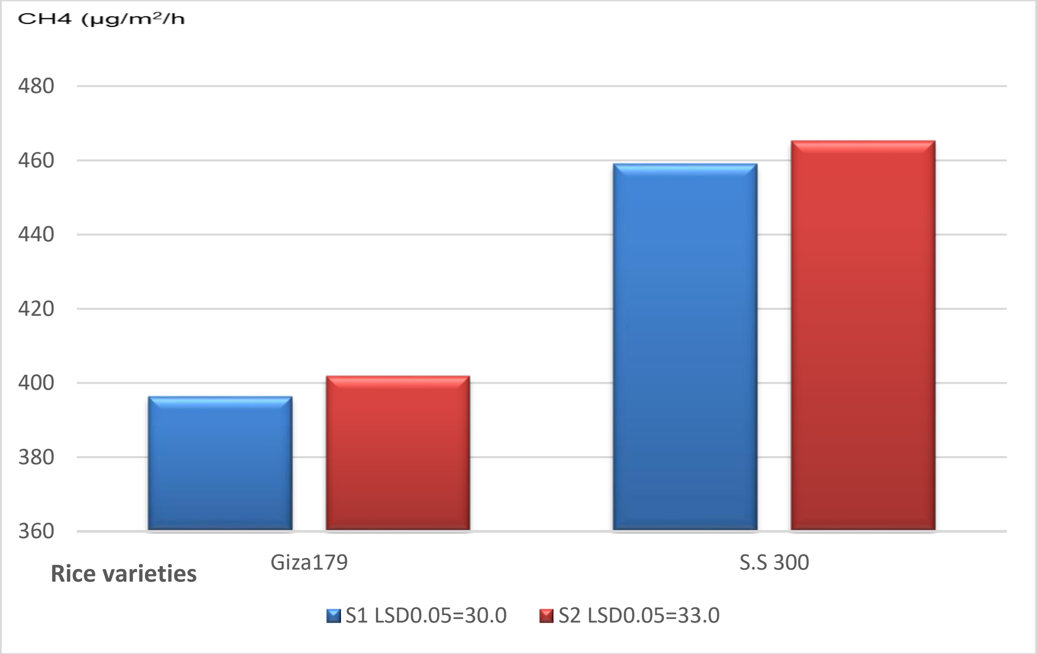

Fig. 4. Methane gas emission of Giza179 and Sakha super300 in 2021and 2022 seasons. **Fig. 4.** S1= season 2021 and S2 = season 2022

Figure5: Methane gas emission as affected by different organic fertilizer in 2021and 2022 seasons

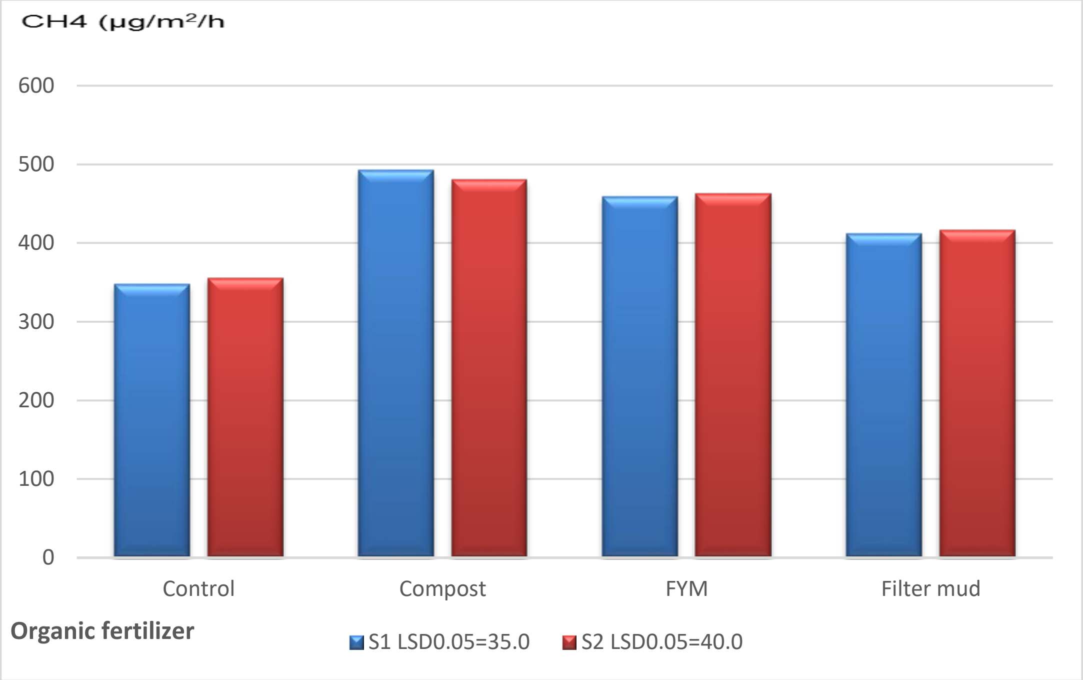

Fig. 5 S1= season2021, S2 = season2022 and compost = Rice straw compost

Different cultivation method, rice cultivars, and organic fertilizer showed prominent differences on CH4 emission gas rates figures (3,4 and5). It was clear that dry seed cultivation methods represented in drill and furrow irrigated rice reduce CH4 efflux than transplanting which gave the biggest emission rate of CH4 during the study season. CH4 emission from Sakha super300 was more than Giza179. Organic fertilizer management could also have contributed to this larger emission rates of CH4 emission, the tested three organic fertilizer increased CH4 emission rate more than the control treatment, however filter mud compost was the best one, since it reduces methane gas emission than farm yard manure (FYM) and rice straw compost (RSC). Moreover, control treatment without application of organic fertilizer gave the lowest value of CH4 emission in both seasons.

Figure6: Methane gas emission affected by the interaction between rice and cultivation method in 2021season

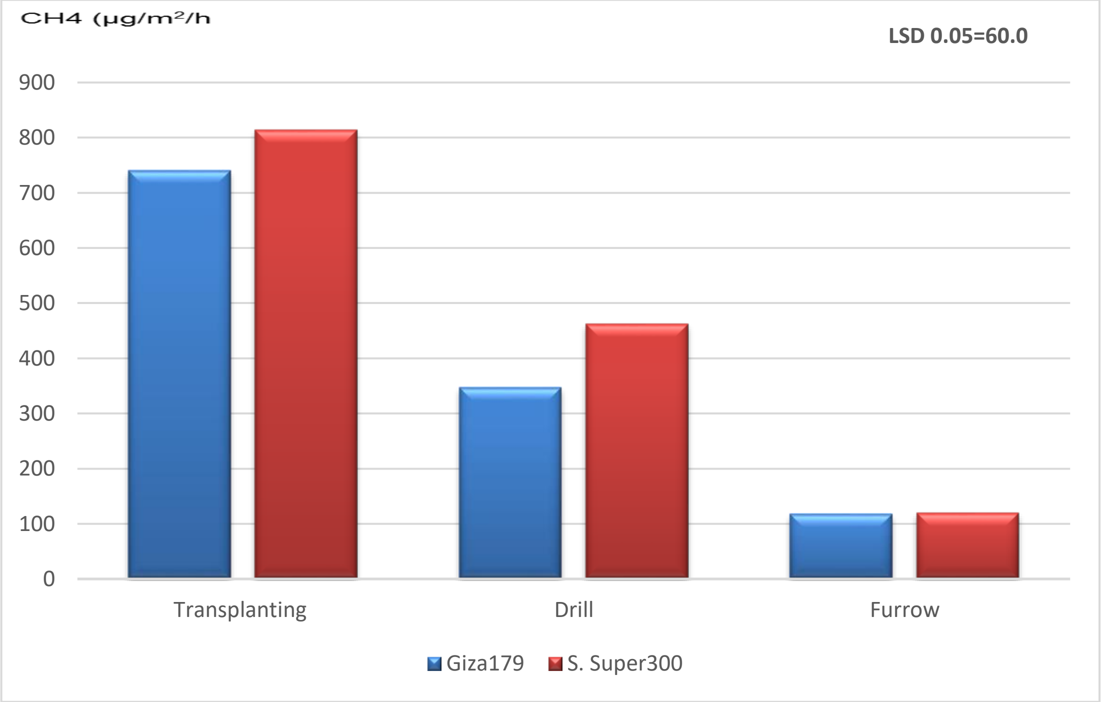

Fig. 6.

Fig. 7. Methane gas emission affected by the interaction between rice and cultivation method in 2022 season

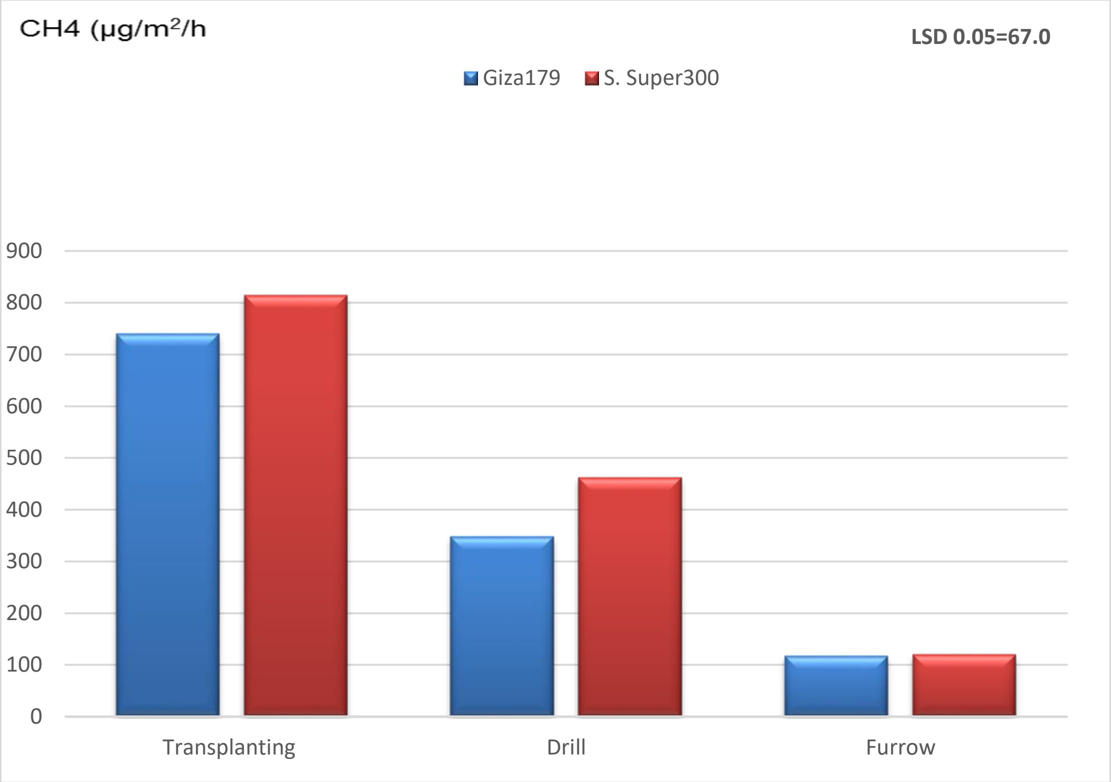

Fig. 7.

Figure 8. Methane gas emission affected by the interaction between rice and organic fertilizer in 2021season

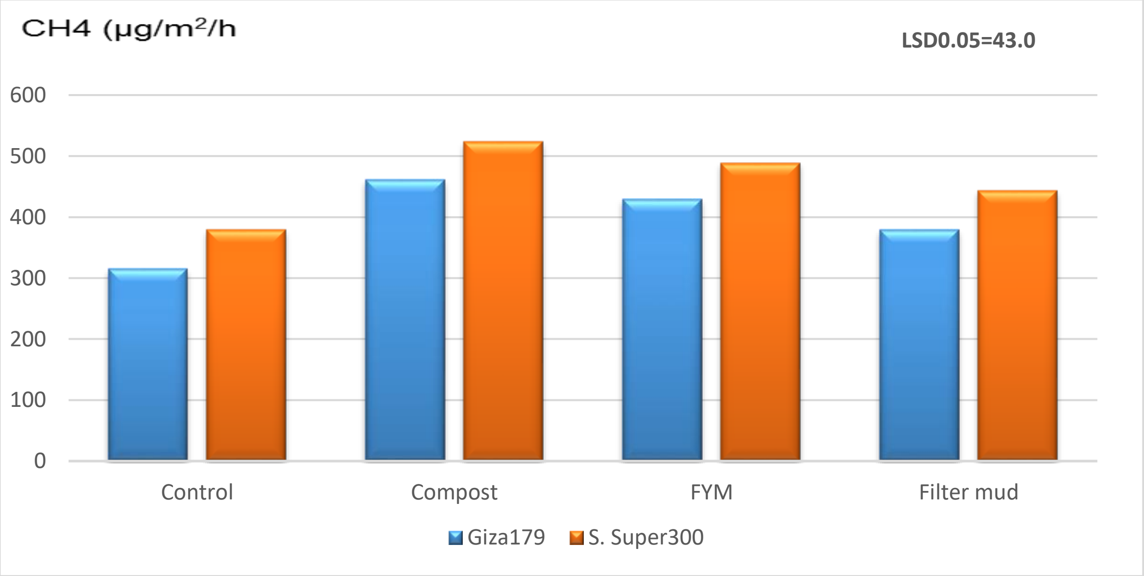

Fig. 8. compost = Rice straw compost

Figure9: Methane gas emission affected by the interaction between rice and organic fertilizer in 2022season

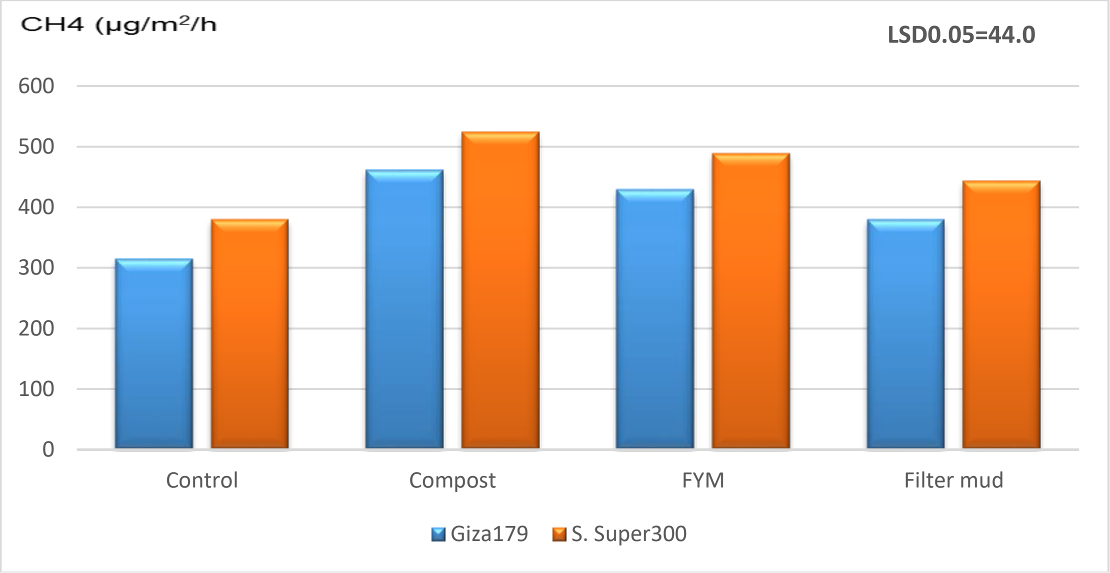

Fig. 9. compost = Rice straw compost

The interaction among the tested treatments was significant during the study seasons (figs 6-9), the maximum value of methane gas emission was observed by Sakha super300 under transplanting, meanwhile the lowest value was achieved by Giza179 under furrow cultivation method figs 6&7. As shown in figures 8 and 9 Giza179 and Sakhasuper300 under control treatment not including implementation of organic fertilizer gave the lowest value of methane gas emission followed by Giza179 fertilized by filter mud compost which produces the lowest rate of methane emission compared with other combinations among treatments in both seasons.

2. Fluorescence index:

The chlorophyll fluorescence parameter is an imperative index to study in plant photosynthetic physiological stage. The initial plant damage caused by stress during photosynthesis is closely related to PSII photochemical efficiency of PS|| (Fv/Fm), and maximal fluorescence (FM).

Table 3. Photochemical efficiency of PS|| (Fv/Fm), maximal fluorescence (Fm) and CO_2 concentration as affected by different cultivation method and organic fertilizer of two rice varieties in 2021 and 2022 seasons

Treatments	**Fv/Fm**		**Fm**		**CO2 (µmol/g)**	
	2021	2022	2021	2022	2021	2022
Cultivation method(C)						
transplanting	0.779a	0.834a	2977a	2931a	80.8b	85.3a
Furrow	0.710b	0.770b	2861b	2849a	83.0ab	85.1a
Drill	0.714b	0.766b	2662c	2656b	84.0a	80.5b
F test	**	**	**	**	*	**
Varieties (V)						
Giza179	0.763a	0.800a	2843a	2719a	84.7a	81.8b
S.S 300	0.705b	0.780b	2824a	2705a	80.6b	85.6a
F test	**	**	NS	NS	**	**
Organic fertilizer(O)						
Control	0.602c	0.659b	2603b	2588c	81.0b	81.9b
RSC	0.779ab	0.836a	2925a	2896ab	81.6ab	86.1a
FYM	0.761b	0.817a	2866a	2837b	84.6a	83.3b
Filter mud	0.795a	0.849a	2940a	2927a	83.5ab	83.3b
F test	**	*	**	*	*	**
Interaction						
C *V	Ns	Ns	Ns	Ns	Ns	Ns
V*O	Ns	Ns	Ns	Ns	Ns	Ns
O*C	Ns	Ns	Ns	Ns	Ns	Ns
V*O*C	Ns	Ns	Ns	Ns	Ns	Ns

*, ** and Ns indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

As shown in Table3 the value of Fv/Fm and FM under aerobic cultivation is lower than transplanting method, low water potential affects electron transport slightly, since the photo inhibitory damage on PSII occurs at high irradiance under water stress conditions. As for rice cultivars behavior, the maximum rate of Fv/Fm and FM was given preferentially by Giza179. Higher rate of Fv/Fm for Giza179 is an indicator of tolerance to the abiotic stress in plants and associated with an increased non-photochemical loss. A significant increase in Fv/Fm by Giza179 mean increasing harvesting of quantum photon and transfer of light energy to the PSI and PSII for carbon dioxide assimilation. Subsequently, a large amount of light energy dissipated in the form of heat energy in mesophyll cells of senescing leaves. Moreover, the effect of applied organic fertilizer was not clear regarding to fluorescence index. Applied compost likely increased the partial pressure of CO_2

3.Some physiological traits:

Super oxide dismutase (SOD), peroxidase (PROX), lipid peroxidase (MDA), chlorophyll a, chlorophyll b, carotenoids and total photosynthetic pigments contents for rice affected by various treatment are presented in Tables4 and5.

Table 4. Physiological traits evaluated under different plant methods, sources of organic fertilizer and rice cultivars in 2021 and 2022 seasons

Treatments	**SOD (U/mg protein/min)**		**PROX (U/mg protein/min)**		**MDA (nmol ml $^{-1}$g $^{-1}$f wt.)**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**
Cultivation method(C)						
Transplanting	45.1c	47.6c	39.1b	40.6c	0.288ab	0.271b
Furrow	248.7a	249.7a	43.8a	44.2a	0.283b	0.268b
Drill	234.9b	238.1b	43.6a	43.2b	0.301a	0.303a
F test	**	**	**	**	*	**
Varieties (V)						
Giza179	190.4a	192.1a	42.0a	42.5a	0.270b	0.262b
S.S 300	162.1b	164.9b	42.4a	42.9a	0.311a	0.300a
F test	**	**	NS	NS	**	**
Organic fertilizer						
Control	165.0c	168.8c	41.5b	42.2	0.304a	0.307a
RSC	173.9b	177.8b	41.8b	42.6	0.308a	0.263b
FYM	176.0b	177.4b	42.9a	43.0	0.285ab	0.271b
Filter mud	190.1a	190.0a	42.5a	42.9	0.266b	0.272b
F test	**	**	*	NS	*	**
Interaction						
V*C	Ns	Ns	Ns	Ns	Ns	Ns
V*O	Ns	Ns	Ns	Ns	Ns	Ns
O*C	Ns	Ns	Ns	Ns	Ns	Ns
V*O*C	Ns	Ns	Ns	Ns	Ns	Ns

*, ** and Ns indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

The production of antioxidant was increased under dry seed cultivation methods than transplanting, MDA refers to deterioration in cell membrane it increased under drill cultivation method compared with furrow irrigated rice(Table4) in standout against, the amount of chlorophyll a, Chlorophyll b, carotenoids and total photosynthetic pigments contents that were increased under transplanting than dry seed cultivation methods**.** Giza179 rice variety was higher than Sakha super300 variety in forming of super oxide dismutase (SOD) activity in both seasons and chlorophyll a only in the first season. Giza179 rice variety also showed less amount of MDA. Insignificant differences were obtained on tests of rice varieties in peroxidase, carotenoids and total pigments contents. Organic fertilizer treatments increased antioxidant and photosynthesis pigments than control treatment, however filter mud compost provide its superiority than others tested fertilizers under study in most of assessed physiological traits. The interaction between the treatments was not significant for the tested physiological traits.

Table 5. Physiological traits different cultivation methods and organic fertilizer of two rice varieties in 2021 and 2022 seasons

Treatments	**Chlorophyll a (mg/g f.w)**		**Chlorophyll b (mg/g f.w)**		**Carotenoids (mg/g f.w)**		**Total pigments contents (mg/g f.w)**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Cultivation method(C)								
transplanting	3.44a	3.46a	1.99a	2.06a	0.644a	0.591a	6.12a	6.11a
Furrow	3.06c	3.13b	1.81b	1.74b	0.568b	0.528b	5.44b	5.40b
Drill	3.33b	2.96c	1.65c	1.67c	0.509c	0.507b	5.49b	5.14b
F test	**	**	**	**	**	**	**	**
Varieties (V)								
Giza179	3.18b	3.16a	1.93a	1.90a	0.592a	0.549a	5.70a	5.61a
S.S 300	3.37a	3.22b	1.70b	1.75b	0.555a	0.535a	5.63a	5.51a
F test	**	**	**	**	Ns	Ns	Ns	Ns
Organic fertilizer (O)								
Control	2.96b	2.70b	1.69c	1.68c	0.472c	0.469c	5.12c	4.85c
RSC	3.33a	3.33a	1.81b	1.83b	0.589b	0.533b	5.73b	5.69b
FYM	3.36a	3.32a	1.85b	1.85b	0.616ab	0.593a	5.83b	5.76ab
Filter mud	3.46a	3.40a	1.92a	1.93a	0.619a	0.573a	6.00a	5.90a
F test	**	**	**	**	**	**	**	**
Interaction								
V*C	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
V*O	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
O*C	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
V*O*C	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

*, ** and Ns indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

4.Some growth characteristics:

Leaf area index, dry matter g hill^{-1} plant height(cm) and number of panicles m^{-2} traits are presented in Table6. The studied growth characteristics increased under transplanting than dry seed cultivation methods. No significant differences were obtained between furrow and drill planting methods.

Table 6. Growth characteristics evaluated under different cultivation method and organic fertilizer of two rice varieties in 2021 and 2022 seasons

Treatments	**Leaf area index**		**dry matter g hill^{-1}**		**Plant height(cm)**		**Number of panicle/m^2**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Cultivation method(C)								
transplanting	4.67a	4.38a	88.7a	81.8a	100.5a	98.5a	439.5a	426.6a
Furrow	4.56b	4.77b	65.6b	68.8c	85.5b	82.4b	367.0b	353.3b
Drill	4.53a	4.29a	78.2b	71.5b	87.08b	84.3b	345.8c	342.5b
F test	**	**	**	**	**	**	**	**
Varieties (V)								
Giza179	5.25a	5.58a	81.4a	83.3a	77.1b	73.8b	418.0a	415.0a
S.S 300	4.76b	5.04b	76.9b	75.1b	104.8a	103.0a	350.2b	333.3b
F test	**	**	**	**	**	**	**	**
Organic fertilizer								
Control	4.38b	4.83b	55.0c	59.6b	85.7b	83.05b	324.4c	318.8c
RSC	5.69a	5.34a	77.2b	74.5a	92.7a	90.5a	391.1b	382.2b
FYM	5.48a	5.49a	82.4a	74.2a	92.6a	89.2a	407.7a	393.3ab
Filter mud	5.46a	5.59a	82.1a	75.9a	92.9a	90.9a	413.3a	402.2a
F test	**	**	**	**	**	**	**	**
Interaction								
V*C	Ns	Ns	Ns	Ns	Ns	Ns	**	**
V*O	Ns	Ns	Ns	Ns	Ns	Ns	**	*
O*C	Ns	Ns	Ns	Ns	Ns	Ns	**	**
V*O*C	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

*, ** and Ns indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

Sakha super300 surpassed Giza179 in plant height and leave area index while, Giza179 produced the maximum value of number of panicles m^{-2} and dry matter g hill^{-1}. The tested organic materials increased growth traits than control, insignificant differences were detected among each other. The interaction between the treatments was not significant for the tested growth characteristics except panicle number m^{-2}(Table6). The maximum panicle number was obtained by Sakha super300 under transplanting methods. In the meantime, the lowest value was obtained by Sakha super300 under drill cultivation method (Table7). Data in (Table8) show that applied filter mud compost without significant difference with FYM was more efficient than RCS concerning increased panicle number for the tested rice varieties. Likewise, filter mud compost was more efficient than the other treatments, under the three tested cultivation methods or panicle number (Table9). It was observed that on the application of organic materials produced positive impact compared with the control.

Table7. Number of panicle and filled grains affected by the interaction between rice and cultivation method

Factors	**Number of panicles(m^{-2})**			**Number of filled grains panicle^{-1}**		
	Transplanting	**Furrow**	**Drill**	**Transplanting**	**Furrow**	**Drill**
	2022					
Giza179	465.0a	394.1b	395.0b	159.9a	109.6d	109.7d
S.S 300	414.1b	340.0c	296.6d	134.8b	126.9c	125.5c
	2022					
Giza179	455.0a	390.0a	400.0a	155.5a	106.1d	104.9d
S.S 300	398.3a	316.0b	285.0b	132.3b	124.9c	124.5c

Table 8. Number of panicle and filled grains/panicle affected by the interaction between rice varieties and organic fertilizer applied

Factors	**Number of panicles (m^{-2})**				**Number of filled grains panicle^{-1}**			
	2021							
	Control	RSC	FYM	Filter mud	Control	RSC	FYM	Filter mud
Giza179	371.1c	414.4b	440a	446.6a	114.3f	126.2e	130.0e	135.1a
S.S 300	277.7d	367.7c	375.5c	380c	108.9e	127.6c	137.1b	142.6a
	2022							
Giza179	373.3c	413.3b	435.5a	437.7a	110.7f	122.3e	126.4d	130.4d
S.S 300	264.4d	351.1c	351.1c	366.6c	109.6d	125.6c	133.1b	141.2a

Table 9. Number of panicle and filled grains affected by the interaction between cultivation method and organic matter

Factors	**Number of panicles(m^{-2})**				**Number of filled grains panicle^{-1}**			
	2021							
	Control	**RSC**	**FYM**	**Filter mud**	**Control**	**RSC**	**FYM**	**Filter mud**
Transplanting	383.3cd	455.0a	460.0a	460.0a	121.5e	148.5c	156.3b	163.1a
Furrow	296.6f	368.3de	396.6bc	406.6b	105.8g	113.2f	124.5e	129.7d
Drill	293.3f	350e	366.6de	373.3d	107.6g	119.2e	120.2e	123.8e
	2022							
Transplanting	376.6bc	443.3a	443.3a	443.3a	119.3e	145.1c	151.5b	159.8a
Furrow	286.6d	356.6c	373.3bc	396.6b	104.6h	111.2fg	119.2e	127.2d
Drill	293.3d	346.6c	363.3c	366.6bc	106.6gh	114.2ef	117.1ef	121 e

5.yield and yield attributes characteristics:

Data of panicle weight g^{-1}, panicle length cm, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1},1000-grain weight g^{-1}, grain yield t fed^{-1}, biological yield t fed^{-1} and harvest index as well as their interaction are listed in **Tables7-15**. Transplanting cultivation method raised grain yield and its attributes than dry seed cultivation methods (Tables10and11). Giza179 was superior to Sakha super300 in panicle weight g^{-1}, number of filled grains panicle^{-1} and grain yield traits, while Sakha super300 was better in the rest yield attributes. Applied of organic fertilizer increased grain yield and its attributes than control treatment, farm yard manure and filter mud compost raised grain yield and its attributes than rice straw compost. The interaction between the treatments was significant for number of filled grains and grain yield during the study seasons, number of filled grains of both varieties increased under transplanting than aerobic cultivation (Table7). Data in Table8 show that number of filled grains for tested varieties increased by applying filter mud compost than other. As for the interaction between cultivation method and organic fertilizer, the highest value of number of filled grains noticed by transplanting and filter mud compost Table (9). The effect of interaction on grain yield among the treatments are listed in tables 12,13,14 and15. From the effect of interaction on grain yield It was observed that, Sakha super300 was better than Giza179 in grain yield under transplanting cultivation method meanwhile, Giza179 better than Sakha super300 under dry cultivation. The highest grain yield for tested rice varieties under dry or transplanting cultivation methods was obtained when they supplied by filter mud compost or farm yard manure.

Table 10. Panicle weight g^{-1}, panicle length cm, number of filled grains panicle^{-1}, number of filled grains panicle^{-1}and number of unfilled grains panicle^{-1}as affected by different cultivation method and organic fertilizer of two rice varieties in 2021 and 2022

Treatments	**Panicle weight g^{-1}**		**Panicle length cm^{-1}**		**Number of filled grains panicle^{-1}**		**Number of unfilled grains panicle^{-1}**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Cultivation method(C)								
transplanting	4.13a	4.02a	22.1a	21.8a	147.3a	143.9a	9.6b	8.01b
Furrow	3.04c	2.94c	17.8c	17.5c	118.3b	115.5b	10.83a	9.75a
Drill	3.28b	3.15b	18.5b	18.1b	117.6b	114.7b	10.9a	9.59a
F test	**	**	**	**	**	**	**	Ns
Varieties (V)								
Giza179	3.31b	3.19b	20.0a	19.73a	126.0b	122.2b	10.3a	9.1a
S.S 300	3.66a	3.55a	18.9b	18.6b	129.1a	127.2a	10.5a	8.95a
F test	**	**	**	**	**	**	**	**
Organic fertilizer								
Control	2.94d	2.84c	18.3d	18.08c	111.6d	110.1d	15.1a	13.7a
RSC	3.43c	3.27b	19.3c	19. 0b	126.9c	123.5b	10.5b	8.34b
FYM	3.70b	3.60a	19.7b	19.3b	133.6b	129.3a	8.64c	7.47b
Filter mud	3.87a	3.77a	20.6a	20.3a	138.9a	129.3a	7.48c	6.88b
F test	**	**	**	**	**	**	**	**
Interaction								
V*C	Ns	Ns	Ns	Ns	**	*	Ns	Ns
V*O	Ns	Ns	Ns	Ns	*	*	Ns	Ns
O*C	Ns	Ns	Ns	Ns	**	**	Ns	Ns
V*O*C	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

*, ** and Ns indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

Table 11. 1000-grain weight g^{-1}, grain yield t fed^{-1}, biological yield t fed^{-1} and harvest index as affected by different cultivation method and organic fertilizer of two rice varieties in 2021 and 2022 seasons

Treatments	**1000-grainweight g^{-1}**		**Grain yield t fed^{-1}**		**Biological yield t fed^{-1}**		**Harvest index**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Cultivation method(C)								
transplanting	26.5a	26.6a	4.99a	4.88a	10.6a	10.7a	0.468a	0.453a
Furrow	23.4c	23.5c	3.61b	3.54b	7.82c	8.03c	0.462a	0.439a
Drill	24.2b	24.5b	3.11c	3.04c	8.17b	8.53b	0.380b	0.355b
F test	**	**	**	**	**	**	**	**
Varieties (V)								
Giza179	24.4b	24.6b	4.10a	4.06a	8.871	9.11	0.461	0.443a
S.S 300	25.0a	25.2b	3.7b	3.58b	8.99	9.21	0.412	0.388b
F test	**	**	**	**	NS	NS	NS	**
Organic fertilizer								
Control	23. 0c	23.2c	3.15c	3.09c	7.77c	8.09c	0.405b	0.378b
RSC	24.9b	25.2b	3.91b	3.80b	8.68b	8.98b	0.448a	0.422a
FYM	25.4a	25.4ab	4.25a	4.20a	9.56a	9.74a	0.442a	0.429a
Filter mud	25.6a	25.7a	4.30a	4.20a	9.51a	9.63a	0.451a	0.435a
F test	**	**	**	**	**	**	**	**
Interaction								
V*C	Ns	Ns	**	**	Ns	Ns	Ns	Ns
V*O	Ns	Ns	**	*	Ns	Ns	Ns	Ns
O*C	Ns	Ns	**	**	Ns	Ns	Ns	Ns
V*O*C	Ns	Ns	*	*	Ns	Ns	Ns	Ns

*, ** and Ns indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test

Table 12. Grain yield affected by the interaction between rice and cultivation method

Factors	**2021**			**2022**		
	Transplanting	**Furrow**	**Drill**	**Transplanting**	**Furrow**	**Drill**
Giza179	4.80b	3.88c	3.60d	4.74b	3.89c	3.56d

S.S 300	5.18a	3.34e	2.61f	5.03a	3.19e	2.51f

Table 13. Grain yield affected by the interaction between rice and organic fertilizer

Factors	**2021**				**2022**			
	Control	**RSC**	**FYM**	**Filter mud**	**Control**	**RSC**	**FYM**	**Filter mud**
Giza179	3.32e	4.15b	4.52a	4.39a	3.28d	4.07bc	4.57a	4.32b
S.S 300	2.97f	3.66dd	3.97c	4.22b	2.89e	3.52d	3.82c	4.08bc

Table 14. Grain yield affected by the interaction between cultivation method and organic matter

Factors	**2021**				**2022**			
	Control	**RSC**	**FYM**	**Filter mud**	**Control**	**RSC**	**FYM**	**Filter mud**
Transplanting	4.14c	5.08b	5.32a	5.42a	4.10b	5.03e	5.21a	5.20a
Furrow	2.99f	3.48e	3.86d	4.09c	2.97e	3.31de	3.83bc	4.04b
Drill	2.31g	3.17f	3.56e	3.4e	2.19f	3.05e	3.56cd	3.3de

Table 15. Grain yield affected by the interaction among rice varieties, cultivation method and organic fertilizer

Factors		**Control**	**RSC**	**FYM**	**Filter mud**
		2021			
Giza179	Transplanting	4.17e	4.75c	5.16b	5.14b
	Furrow	2.96jk	3.79 fg	4.27de	4.51cd
	Drill	2.84k	3.92ef	4.15e	3.51gh
Sakha super 300	Transplanting	4.11e	5.41ab	5.49a	5.71a
	Furrow	3.03jk	3.17ijk	3.46ghi	3.6fg
	Drill	1.78m	2.42i	2.97	3.28hij
	2022				
Giza179	Transplanting	4.03cde	4.81ab	5.12a	5.01a
	Furrow	3.09ghi	3.62d-g	4.40cde	4.44bc
	Drill	2.74i	3.79def	4.20cd	3.51e-h
Sakha super 300	Transplanting	4.18cd	5.24a	5.29a	5.4a
	Furrow	2.85i	3.01hi	3.26f-i	3.6d-g
	Drill	1.64 k	2.32j	2.92hi	3.18ghi

6.Water saving

Data shown in **Table16** verified that the total water used and, water use efficiency for rice varieties were significantly influenced by the different cultivation methods in both seasons.

Table 16. Total applied water (m^3/fed) and water use efficiency (WUE) for tested varieties under different cultivation method

Factors	**Giza179**				**Sakha super300**			
	Total applied water		**WUE**		**Total applied water**		**WUE**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Transplanting	5000	4900	0.96	0.96	6000	6100	0.86	0.82
Furrow	3800	3750	1.0	1.03	4000	4050	0.83	0.85
Drill	4000	3940	0.90	0.90	4500	4590	0.58	0.54

It was observed that Giza179 consumed the lowest amount of water and transplanting cultivation method used the highest amount of water throughout the season. It was also observed that, the best cultivation method for higher water use efficiency was furrow for Giza179, and for Sakha super300 transplanting was the best method. Carrijo *et al.,(*2017) noticed that alternate wetting and drying (AWD) improved water productivity (grain yield per unit water) by 24% without reduction in yield. Regarding the different organic fertilizer sources and its impact on water use efficiency data shown in Table17, details that applied of organic matter increased water use efficiency compared with control treatment. water use efficiency was increased by applied filter mud compost followed by farm yard manure. Rice straw compost came in the last order regarding increase water use efficiency for the tested rice varieties in both seasons.

Table 17. Water use efficiency (WUE) for tested varieties under different cultivation method and different organic fertilizer sources

Rice varieties	**Cultivation method**	**Control**		**RSC**		**FYM**		**Filter mud**	
		2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Giza179	Transplanting	0.83	0.82	0.95	0.98	1.03	1.04	1.02	1.02
	Furrow	0.77	0.81	0.99	0.96	1.12	1.17	1.18	1.18
	Drill	0.71	0.69	0.98	0.96	1.03	1.06	0.87	0.89
	mean	0.77	0.77	0.97	0.97	1.06	1.09	1.02	1.03
Sakha super 300	Transplanting	0.68	0.68	0.90	0.85	0.91	0.86	0.93	0.88
	Furrow	0.75	0.70	0.79	0.76	0.86	0.80	0.92	0.90
	Drill	0.37	0.35	0.52	0.50	0.64	0.63	0.71	0.99
	mean	0.60	0.58	0.74	0.70	0.80	0.76	0.85	0.92

The applied new strategies for water saving cultivation methods, may have negative impact on soil organic matter and soil fertility compared to flood irrigation or transplanting cultivation method, so applied of organic fertilizer is important for soil nutrient availability to maintain rice yield in the long term (Pengetal., 2011, Carrijo *et al.,*2017 and John *et al.,* 2019).

DISCUSSIONS

1-Methane gas emission:

cultivars, cultivation methods and organic amendments are major causes for variations of CH4 fluxes from rice fields. CH4 flux from rice fields were closely related to organic amendment, water management (Wang *et al.,* 2012) and rice varieties (Banger *et al.,* 2012). Methane gas emission varied during different rice growth stages may be due to availability of methanogenesis bacteria (Wang *et al.,* 2018). Giza179 rice variety can reduce methane emission may be due to methane release from rice varieties is influenced by genetic factors, morphology, plant physiology, media, and plant growth environment, cultivation of short duration varieties can effectively reduce methane emissions from paddy soils (Gu *et al.,* 2022). Methane gas flux increase under transplanting with flooded rice which induce no free oxygen availability and this conditions favorable form methanogen bacteria (Zehnder and Stumm., 1988 and Gu *et al.,* 2022). Rice straw followed by green manure increase level of gas emission than others, rice straw applied at a rate of 6 t ha^{-1} (dry weight) before rice transplanting, increases the CH4 emission in 3.2 times than fields without any organic amendment. However, straw applied off-season is an effective way to reduce CH4 emission from rice fields (Wang *et al.,* 2018). Organic materials under flooded conditions contributed to increase CH4 emission this might be due to organic materials can liberate carbon dioxide and methanogens can easily produce methane from carbon dioxide reduction. Then, application of organic fertilizers created a suitable condition for reproduction and methane formation of methanogenic bacteria (Brahima *et al.,* 2017). Methane emissions from rice fields do not only depend on rice cultivars, rice growth stages, cultivation method and type of organic matter application, but also depend on another factors as root exudations, which were not considered in this study so in future work should be considered.

2. Fluorescence index:

photochemical efficiency of PS‖ (Fv/Fm) and maximal fluorescence (FM) can be used for the selection of low water input-adaptive genotypes and it represents the maximum photochemical efficiency of photosystem II (PSII), which correlated to quantum yield of net photosynthesis, means that, decreasing in Fv/Fm could reflect the achieved decrease in carbohydrate biosynthesis, (Na *et al.,* 2014, Chen *et al.,* 2015, Nadzariah *et al.,* 2018 and Hajihashemi *et al.,* 2020). Moreover, the effect of applied organic fertilizer was not clear regarding to fluorescence index. Applied compost likely increased the partial pressure of CO_2 due to increased microbial activity during incubation and organic fertilizer release of CO_2 and organic acids during the decomposition(Wong *et al.,* 2009 and Santors *et al.,* 2005).

3.physiological traits:

Aerobic rice cultivation as furrow irrigated rice and drill rice increased ATPs which raised antioxidants, SOD, PROX and lipids peroxidase (Kirk., 2004 and Zayed *et al.,* 2023). Aerobic cultivation represents an attractive solution to water scarcity on agricultural land around the world and the physiological traits responses of rice to dry rice cultivation remain poorly understood compared with flooded cultivation, and fewer rice varieties are suited to aerobic cultivation (Yoichiro and Katsura 2014). Rice physiological traits enhanced by compost addition could be attributed to an accumulation of essential macronutrients by soil physical characteristics changes for better, organic amendments enhance stability and promote the soil of aggregates, thereby increasing soil permeability and increase water holding capacity. The addition of organic amendments resulted in significant flocculation and huge number of soil aggregates formation, enhancing the soil porosity and water infiltration (Wang *et al.,* 2014 and Reina *et al.,* 2022). Briefly, compost can offer an improvement for plants in the short term. Applications of compost favors the availability of nutrients in the soil and in turn improves the plant mineral nutrition (Munns *et al.,* 2020).

4.Some growth characteristics:

The variation between the tested rice varieties in some growth traits was possibly due to efficient utilization of sun light, and ability of the variety to induce higher photosynthetic activity and translocation of assimilated product from source to sink (Mikhael *et al.,* 2018). Transplanting cultivation method increases growth traits compared with dry cultivation this could be due to flooded conditions with available water for plant optimistic cell division and elongation, root growth by higher nutrient availability and absorption, resulting in higher vegetative growth and total dry matter by increasing water supply for rice (Kumar and Rajitha 2019) and Hossain *et al.,* 2020). It was observed that on the application of organic materials produced positive impact compared with the control., Organic materials are decomposed by microorganisms of the soil, which was contributed to high nutrient availability in the soil, and the growth traits increased by organic fertilizer may be due to the plant response to compost application can be enhanced according to the positive effect on the soil properties (Anan Polthanee., 2008 and Reina *et al.,* 2022).

5. Yield attributes characteristics:

The differences between the tested varieties in some yield attributes traits may be due to the ability of variety to enhanced photosynthetic activity and translocation of assimilated products from source to sink by well-organized utilization of sun light, this ability eventually resulted in higher leaf area index, dry matter production and plant height similar data was recorded by (Gaballah *et al.,* 2021). Low input water caused early senescence, shortened grain-filling period, reduced photosynthesis and increased soluble sugars remobilization from grains to other vegetative parts. If the stress occurs at the reproductive stage (Gaballah *et al.,* 2021), application of organic materials has a positive effect on the growth and productivity of various crops. It helps the plant to improve the grain filling process and introduce healing to the soil by enhancing the physical, chemical, and microbial activity, delivering growth-regulating substances causing better grain yield (Ma *et al.,* 2021andMohammad *et al.,* 2021). Application of organic fertilizer under dry seed cultivation method increases growth traits and grain yield (Anan Polthanee. 2008 and Reina *et al.,* 2022).

6.Grain yield:

The grain yield depends upon photosynthetic processes which can improve physiological processes inside the plant such as photosynthesis, enzyme activity, the growth parameters, such as higher leaf area that allows a better light interception and crop growth and higher yield. Plant height, and dry matter were able to increase the total and also later growth, which lead to segmentation of dry matter production and its spreading in different plant parts as well as resulting in more grain filling and weight panicles, which was attributed to high grain yield (Balaji *et al.,* 2015 and Hossain *et al.,* 2020). Dry seed cultivation method increases ATPs and increased antioxidants and defense system, this was reflected in improved growth traits, biomass and productivity of rice (Kirk., 2004 Zayed *et al.,* (2023). Application of organic fertilizer (RSC, FYM and filter mud) improved the soil properties by reducing soil pH value and amounts of soluble and exchangeable sodium moreover, increased forms of both soluble and exchangeable calcium, and some nutrients to rice plant Shang *et al.,* (2020). The most advantageous mineral supply is independent of nutrition farmyard manure and filter mud caused enlarge available nitrogen, phosphorus and potassium for plant (Negm *et al.,* 2003, Moustafa., 2005, Salim *et al.,* 2018 and Shang *et al.,* 2020).

Conclusion:

The grain yield of rice does not depend on the amount of water supplied to the crop but it depends on the 'health and wealth' of the soil combined with better management of the crop and choosing the appropriate variety. Rice is a critical food that cannot be dispensable or replaceable to reduce methane gas emission. Then, an alternative cultivation method is key to saving water and reducing the climate change problem along with plied organic fertilizer. Giza179 cultivated by furrow method accompanied by filter mud compost or farm yard manure can be effective to reduce methane gas emission, save water and induce acceptable grain yield.

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تأثير طرق الزراعة الهوائية على انبعاث الميثان, البصمة المائية وإنتاجيه الأرز تحت مصادر مختلفة من التسميد العضوي

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الأرز المغمور بالماء مصدر لانبعاث غاز الميثان الذي يعتبر مسبب اساسى للاحتباس الحراري والتغيرات المناخية، واستهلاك كميات مياه كبيرة رغم ندرتها في مصر. كان الغرض من الدراسة وضع الاستراتيجيات التي تخفف من أثار هذه المشاكل وذلك باختبار المواد العضوية تحت طرق زراعه مختلفة للأرز وتأثيرها على انبعاث غاز الميثان وإنتاجيه الأرز. أقيمت تجربتان حقليتان بمحطة بحوث سخا الزراعية خلال موسمي الزراعه2021 و2022 .استخدم في التجربة تصميم القطاعات المنشقة مرتين في ثلاث مكررات حيث احتوت القطع الرئيسية على طرق الزراعة وهى طريقه الزراعه الشتل وطريقه الزراعه التسطير بالإضافة إلى الزراعة على خطوط واحتوت القطع الشقية الأولى على الأصناف جيزه179 وسخاسوبر300 والقطع الشقية الثانية احتوت على المواد العضوية وهى كومبوست قش الأرز السماد البلدي وأيضا كومبوست بقايا القصب بالإضافة إلى معامله المقارنة. أوضحت الدراسة إن صنف الأرز سخا سوبر300 له القدرة على زيادة انبعاث غاز الميثان أكثرمن الصنف جيزه179. كميه غاز الميثان المنبعثة تعتمد على نوع المادة العضوية المستخدمة حيث جاء في المرتبة الأولى كومبوست قش الأرز ثم السماد البلدي وكان التفوق لكومبوست بقايا القصب حيث كان اقلهم في انبعاث غاز الميثان. الزراعة الجافة كانت اقل في انبعاث غاز الميثان بالمقارنة بالزراعة الشتل كما أدت إلى زيادة الجهاز الدفاعي للنبات أكثر من طريقه الشتل .أما عن المحصول ومكوناته فزاد بطريقه الشتل بالمقارنة بطرق الزراعة الجافة وأيضا بإضافة المادة العضوية بالمقارنة بمعامله المقارنة. كان الصنف جزه 179 أفضل من الصنف سخاسوبر300تحت طرق الزراعة الجافة. استخدام طريقه الزراعة على خطوط للصنف جيزه179 والتسميد بكومبوست بقايا القصب يمكن أن يقلل غاز الميثان ويوفر كميه مياه الري وأيضا يزيد من محصول الأرز.

الكلمات المفتاحية: طرق الزراعة ، نظام الدفاع ، انبعاثات غاز الميثان ، المواد العضوية ، الأرز