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Greenhouse Gas Emission from Cauliflower Grown under Different Nitrogen Rates and Mulches

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Authors' contributions

This work was carried out in collaboration between the two authors. Both authors designed the study, wrote the protocol, managed the literature searches and managed the experimental process. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during the two successive seasons of 2012/2013 and 2013/2014 at El-Bosaily farm, El-Behira governorate, Egypt, to study the effect of different nitrogen rates and mulch treatments on plant growth and yield of cauliflower (*Brassica oleracia* var. *botrytis*). The study includes three mulch treatments (transparent and black polyethylene sheets, and bare soil as a control) and four N rates 30, 45, 60 and 75 kg/feddan (1 feddan = 4200 m^2 and hectare = 2.4 feddan) designed in a split plots with three replicates. The greenhouse gas (GHG) emissions of N_2O and CO_2 from N fertilization were calculated for different treatments. Regarding the polyethylene (PE) mulch, data revealed that transparent PE recorded the highest significant values of cauliflower growth characters during the two studied seasons. Increasing N rate up to 60 kg/feddan enhanced cauliflower growth using different polyethylene mulch treatments; yield was not increased significantly with increasing N rate up to 75 kg/feddan. The highest significant cauliflower yield was obtained by using 60 kg N/feddan combined with transparent mulch, while the lowest yield was obtained in case of 30 kg N/feddan combined with bare soil treatment. Chemical analysis of cauliflower leaves at harvest revealed that the percentage of N, P and K increased

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significantly with increasing N rate up to 75 kg/feddan. Polyethylene mulch treatments increased N, P and K percentages significantly in comparison with bare soil treatment. Moreover, the greenhouse gas emissions (N_2O and CO_2) from fertilization increased but the emission rates (kg CO_2/kg yield) were decreased by increasing N rate due to the highest cauliflower production. The highest yield with low emission was obtained by 60 kg N/feddan.

Keywords: GHG emission; polyethylene mulch; nitrogen rate; cauliflower.

1. INTRODUCTION

Cauliflower (*Brassica oleraceae* var. *botrytis* L.) is a vegetable crop grown for its white curds. It is a cool season crop that demands high levels of nitrogen to maximize yields. The N fertilization affects cauliflower development in terms of yield, quality and aspects of N metabolism. The cauliflower curd yield increased with N applications [1]. Moreover, N fertilization showed a limited effect on storage loss of heads.

In modern agriculture, fertilizers have often been over-applied to maximize crop production. Environmental issues associated with overuse of N fertilizers are of concern. The N nutrient not absorbed by the crop is lost from the soil by leaching or denitrification with NO/N_2O emission. The NO_3^- levels in groundwater close to farms is a major environmental and social concern impacted by N application [2]. Direct sources include N_2O, which is emitted directly to the atmosphere from cultivated fertilized soils [3]. Indirect emissions result from transport of N from agricultural systems into surface and ground waters through surface runoff and drainage as well as emission as ammonia or nitrogen oxides and deposition elsewhere, causing N_2O production. Methodologies for calculating both direct and indirect emissions of N_2O are related to agricultural production. It takes into account anthropogenic N inputs including synthetic fertilizers, animal wastes and other organic fertilizers, biological N fixation by crops, cultivation of organic soils, along with mineralization of crop residues returned to the field [4].

Gases that trap heat in the atmosphere are called greenhouse gases (GHGs); each of these gases (i.e. N_2O, CO_2, CH_4, O_3, etc.) can remain in the atmosphere from a few years to thousands of years. All of these gases remain in the atmosphere long enough to become well mixed, meaning that the amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emission. Global Warming Potential (GWP) has been calculated to reflect how long it remains in the atmosphere, on average, and how strongly it absorbs energy. Gases with a higher GWP absorb more energy than gases with a lower GWP, and thus contribute more to global warming. For example, N_2O has a radiative warming effect which is about 300 times that of CO_2, the dominant GHG [5]. Management practices that can influence emission of N_2O from agricultural soils include N fertilizers (rate, type, timing and application method), crop, tillage, residue management, and irrigation [6]. Decreasing N fertilizer rate may reduce GHG emission [7].

The mulch determines its energy-radiating behavior and its influence on the microclimate around the plant. Today transparent, black, and white mulches dominate in the commercial vegetable production over the world. Transparent and translucent mulches promote a relatively large net radiation at the soil surface, increase soil heat flux and as a consequence, both minimum and maximum soil temperatures are increased [8]. Row covers are a flexible transparent covering which is installed over plants to reduce the water needs and increase air temperature around the crop. Furthermore, their usage has been associated with increased plant growth, higher yields and earliness of harvest [9]. The crop varies in response to polyethylene mulch covers depending on cultivar, materials used and environmental conditions. The beneficial responses of plants to polyethylene mulch, such as higher total yields, earlier production and better fruit quality have been discussed by many authors [10-12]. Mulch can provide additional benefits beyond temperature, moisture and erosion control; a moderate GHG flux is one of such benefits. Application of mulch to cultivated soil increases soil organic carbon (SOC) concentrations [13]. It also has beneficial effects on SOC sequestration and strongly influences the temporal pattern of CO_2 emission from soil [14].

Thus, the aim of this study was to evaluate the effect of different applied rates of N fertilizer and mulch treatments on the growth, yields of cauliflower and also to determine GHG emission from different N fertilization rates.

2. MATERIALS AND METHODS

2.1 The Field Experiment

The experiment was carried out at El-Bosaily farm, El-Behira Governorate, in the North Coast of Egypt. The study included three mulch treatments viz. transparent and black polyethylene sheets, and bare soil as a control, and four N rates viz. 30, 45, 60 and 75 kg/feddan. The recommended N for cauliflower plant was 45 kg/feddan (feddan = 4200 m^2 and hectare = 2.4 feddan).

The permanent wilting point (PWP) and field capacity (FC) of the experimental soil, *Typic Torripsamments*, were determined according to [15]. Some soil physical and chemical properties were investigated as described by [16-18] and the results have presented in Table 1. Soil temperature was measured by soil thermometer at 15 cm depth; it was recorded daily at mid-day during the two studied seasons. The same amount of drip irrigation was applied for all treatments (EC of the water used for irrigation was 0.82 dS m^{-1}).

Five-week old seedlings of healthy cauliflower cv. Amshiry were transplanted on one side of the ridges at a distance of 50 cm on October 18, 2012 and October 15, 2013 for the first and second seasons, respectively. At the end of the two seasons, samples of five plants of each experimental plot were taken to determine growth parameters (plant height, number of leaves, leaf fresh weight, leaf dry weight per plant and stem diameter). The harvesting period was from February 15 to March 5 in the seasons of 2013 and 2014, respectively. At harvesting stage, ten leaves were obtained from five cauliflower plants that were selected from the middle row of each plot. Nutrient contents (N, P and K) were evaluated in the indicated leaves [19].

2.2 Greenhouse Gas Emission from Nitrogen Fertilization in the Experimental Soil

The aerobic microbial oxidation of ammonia to nitrate is called nitrification, while denitrification is the reduction of nitrate to gaseous nitrogen (N_2). Both reactions produce the intermediate gaseous nitrous oxide (N_2O) through microbial activities in the soil and eventually this gas is released to the atmosphere. The emission of N_2O from field was estimated according to [6]; the following equation was adopted:

$$N_2O \text{ emission} = [1.47 + (0.01 \times F)] \times N_2O_{MW} \times N_2O_{GWP}$$

Where:

F	Mass of N applied from synthetic fertilizer, kg N ha^{-1}
N_2O_{MW}	Ratio of molecular weight of N_2O to 2N, kg N_2O (kg N)$^{-1}$
N_2O_{GWP}	Global Warming Potential for N_2O, kg CO_2-e (kg N_2O)$^{-1}$

The GWP value of 298 for N_2O used in the protocol (N_2O_{GWP}) is the 100-year value used in the most recent IPCC fourth assessment report [20]. The CO_2-e equivalent emission for each gas (CO_2, N_2O and CH_4) were summed together to give total CO_2-e.

2.3 Experimental Design and Statistical Analysis

Split plot design with three replicates was used. Nitrogen rates were randomly arranged in the main-plots and mulch treatments were distributed randomly in the sub-plots. Data were statistically analyzed using statistical analysis system (SAS) program [21]. The means that were significant were separated using Duncan's New Multiple Range Test (DNMRT) at P≤0.05.

Table 1. Some physical and chemical characteristics of the surface layer of the experimental soil (0-30 cm) before crop cultivation

Particle size distribution, %			Texture class	SP	FC	PWP	BD	$CaCO_3$	OM
Sand	Silt	Clay		%			g cm^{-3}	%	
85.1	5.60	9.30	Sandy	25.1	14.8	4.70	1.60	1.03	0.06
pH	EC_e	Soluble ions, meq L^{-1}							
(1:2.5)	dS m^{-1}	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
7.68	1.20	2.95	1.76	6.33	0.96	n.d*	2.98	7.80	1.22

** n.d means not detected*

3. RESULTS AND DISCUSSION

3.1 Soil Temperature

The average soil temperature at 15 cm soil depth in each treatment, in November, December, January and February of 2012/2013 and 2013/2014, is shown in Fig. 1. During the crop cycle, the highest soil temperature was obtained under conditions of the transparent polyethylene mulch (Fig. 1). During the same period, soil temperature under black polyethylene mulch was lower than under the transparent polyethylene mulch by 1-2℃. Soil temperature in control (bare soil) was lower than polyethylene mulch treatments. The obtained results were in agreement with those obtained by [10,22] who observed that the un-mulched plots had the lowest soil temperature (1.0-3.8℃ lower) at different times since planting compared to polyethylene film mulched plots.

3.2 Vegetative Characteristics

The obtained results (Table 2) revealed that mulch and N application rate treatments significantly affected cauliflower vegetative characteristics (plant height, number of leaves, total leaf fresh and dry weight and stem diameter) during the two growing seasons. The highest N rate of 75 kg/feddan produced the highest vegetative characteristics; 60 kg N treatment came in the second order followed by that of 45 kg N; 30 kg N produced the lowest values with significant differences among treatments. Regarding the mulch treatments, data indicated that transparent polyethylene mulch resulted in the highest vegetative characteristics followed by black polyethylene mulch with significant difference between them; the lowest values were obtained in case of control treatment.

The interaction between N rate and mulch treatments was significant for vegetative characteristics during the two growing seasons. The highest values were obtained in cauliflower plants grown using 75 kg N/feddan combined with transparent polyethylene mulch treatment followed by those provided with 60 kg N combined with transparent polyethylene mulch and 75 kg N combined with black polyethylene mulch treatment. The lowest vegetative growth was obtained from plants provided with 30 kg N/feddan treatment along with control. The researchers opined that mulching contributed positively to higher soil temperature and consequently improving growth and yield [23]. While reduced N supply to plants considerably reduced the plant growth [24]. Reductions in growth of N-limited plants correlated with decreases in leaf area, fresh and dry weight along with reallocation of carbon from shoots to roots and a reduction in net assimilation were obtained.

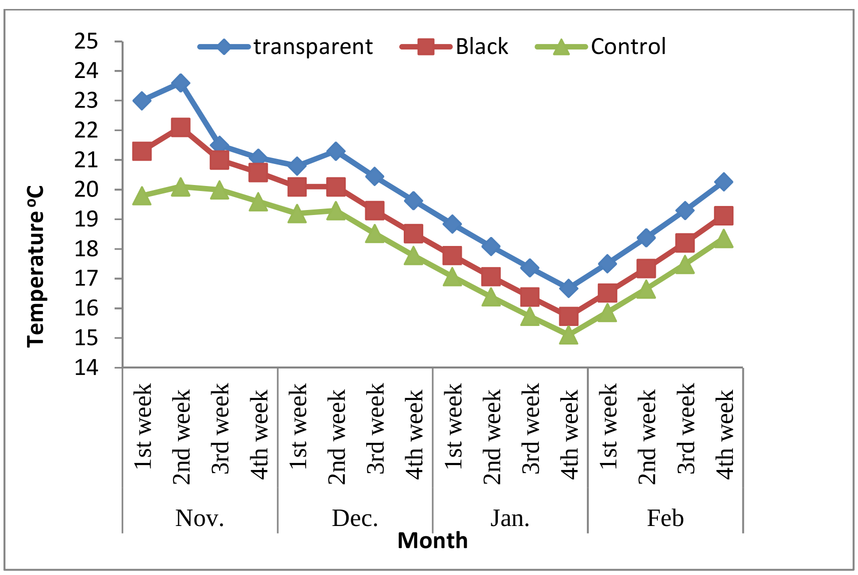

Fig. 1. The average mean soil temperature under transparent, black mulch and control during growing seasons of 2012/2013 and 2013/2014

Table 2. Effect of nitrogen rate and mulch on vegetative characteristics of cauliflower during the studied two seasons of 2012/2013 and 2013/2014

	2012/2013				2013/2014			
Nitrogen rate, kg/feddan (A)	**Polyethylene mulch treatments (B)**			**Mean (A)**	**Polyethylene mulch treatments (B)**			**Mean (A)**
	Black	**Transparent**	**Control**		**Black**	**Transparent**	**Control**	
				Plant height (cm)				
30	61 h	69 f	52 i	**61 D**	64 h	72 f	56 i	**64 D**
45	70 f	77 c	60 h	**69 C**	72 f	78 d	62 h	**71 C**
60	75 d	81 b	66 g	**74 B**	77 d	84 b	67 g	**76 B**
75	79 bc	85 a	72 e	**79 A**	82 c	87 a	75 e	**81 A**
Mean (B)	**71 B**	**78 A**	**63 C**		**74 B**	**80 A**	**65 C**	
				No. leaves/plant				
30	12.1 f	12.6 e	10.8 h	**11.8 D**	13.1 f	14.0 e	12.0 h	**13.0 D**
45	12.5 e	13.4 d	11.5 g	**12.4 C**	13.8 e	14.8 d	12.7 g	**13.7 C**
60	13.8 c	14.1 c	12.7 e	**13.5 B**	14.8 d	15.6 c	14.0 e	**14.8 B**
75	15.1 b	16.3 a	13.8 c	**15.1 A**	16.7 b	17.8 a	15.3 c	**16.6 A**
Mean (B)	**13.3 B**	**14.1 A**	**12.2 C**		**14.5 B**	**15.4 A**	**13.4 C**	
				Fresh weight of leaves (kg/plant)				
30	1.25 g	1.35 f	1.07 h	**1.22 D**	1.29 g	1.39 f	1.10 h	**1.26 D**
45	1.36 f	1.49 e	1.22 g	**1.36 C**	1.40 f	1.53 e	1.26 g	**1.40 C**
60	1.62 d	1.72 c	1.43 e	**1.59 B**	1.67 d	1.78 c	1.47 e	**1.64 B**
75	1.79 b	1.89 a	1.51 e	**1.73 A**	1.85 b	1.95 a	1.56 e	**1.78 A**
Mean (B)	**1.51 B**	**1.61 A**	**1.31 C**		**1.55 B**	**1.66 A**	**1.35 C**	
				Dry weight of leaves (g/plant)				
30	187 h	203 g	161 i	**184 D**	206 h	223 g	177 i	**202 D**
45	204 g	223 ef	184 h	**204 C**	225 g	245 ef	202 h	**224 C**
60	244 d	259 c	215 f	**239 B**	268 d	284 c	236 f	**263 B**
75	269 b	283 a	227 e	**260 A**	296 b	311 a	249 e	**285 A**
Mean (B)	**226 B**	**242 A**	**196 C**		**249 B**	**266 A**	**216 C**	
				Stem diameter (cm)				
30	5.41 e	5.51 c	5.19 g	**5.37 C**	5.74 e	5.86 d	5.48 h	**5.69 C**
45	5.46 d	5.53 c	5.23 g	**5.41 C**	5.76 e	5.88 cd	5.53 g	**5.72 C**
60	5.54 c	5.64 b	5.28 f	**5.48 B**	5.90 cd	5.95 b	5.55 g	**5.80 B**
75	5.64 b	5.85 a	5.40 e	**5.63 A**	5.93 bc	6.14 a	5.69 f	**5.92 A**
Mean (B)	**5.51 B**	**5.63 A**	**5.28 C**		**5.83 B**	**5.96 A**	**5.56 C**	

This is a factorial experiment from two factors: nitrogen rates (A), polyethylene mulch treatments (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant

3.3 Yield

Application of 75 kg N/feddan in cauliflower increased the total yield (ton/feddan), curd weight per plant and curd diameter compared to the other N treatments during the two tested seasons (Table 3). The 60 kg N came in the second order without significant differences with 75 kg. These results agree with those who found that maximizing the nitrogen use efficiency of crop production can be achieved by (i) optimizing the supply of N to meet the requirements of crop during growth and development and (ii) growing N-efficient crop genotypes [25]. There is much advantage to be derived from using economic rate that will enhance higher nitrogen use efficiency and maximize production based on the value of increasing N input; the decline was also observed in nitrogen use efficiency in maize plants [26].

Regarding the effect of polyethylene mulch treatments, data revealed that transparent polyethylene mulch recorded the highest values of yield in the two studied seasons followed by black polyethylene mulch (Table 3). The lowest yield was obtained by control treatment with significant difference with other treatments. Polyethylene mulch modified root zone temperature, which has been shown to have an important role in plant growth and yield [23]. Several investigations have demonstrated that transparent and black polyethylene mulches increased yield and improved crop growth of many vegetable crops [11,22].

Referring to the interaction effect between N rate and polyethylene mulch, data indicated that increasing N rate up to 60 kg, led to increase in cauliflower yield under polyethylene mulch; however, increasing N rate more than 60 kg/feddan led to no significant difference in cauliflower yield. The highest yield was obtained in cauliflower plants applied with 75 kg N/feddan with transparent polyethylene mulch followed by 60 kg N with transparent polyethylene mulch without significant differences between them. The lowest yield was obtained in plants in the control treatment with different N rates. Transparent polyethylene mulch gave higher yield and heavier fruit than the other applications which could be explained in the light of beneficial effects of polyethylene mulch which enables retention of soil moisture and prevents soil temperature to rise up at the end of vegetative phase and enables increases in the CO_2 content, which finally results in increasing photosynthesis [27,28].

Of course, the increases in yield might be due to the increased utilization of N fertilizer in stimulating meristimatic activities. The accumulation of synthesized metabolites resulted in high dry matter accumulation and finally high yield. The obtained results were relatively different and it was found that increasing N rate up to 60 kg/feddan had no effect on cauliflower yield [24,29].

3.4 Nutrient Content

The obtained results in Table 4 showed that the N rate and mulch treatments significantly affected the uptake of N, P and K by cauliflower plants during the two studied growing seasons. The highest N, P and K percentages in the cauliflower leaves were obtained by 75 kg N treatment followed by that of 60 kg N while the lowest N, P and K contents were obtained by 30 kg N treatment.

Mulch treatments significantly affected the N, P and K percentages. The transparent polyethylene mulch resulted in the highest average values in cauliflower plants followed by that of black polyethylene mulch. The lowest N, P and K percentages were obtained in case of control treatment during the two studied seasons.

Table 3. Effect of nitrogen rate and mulch on yield characteristics of cauliflower in the two studied seasons of 2012/2013 and 2013/2014

	2012/2013				2013/2014			
Nitrogen rate, kg/feddan (A)	**Polyethylene mulch treatments (B)**			**Mean (A)**	**Polyethylene mulch treatments (B)**			**Mean (A)**
	Black	**Transparent**	**Control**		**Black**	**Transparent**	**Control**	
				Curd weight (kg/plant)				
30	1.15 g	1.22 h	1.07 k	**1.15 C**	1.20 g	1.27 h	1.11 k	**1.19 C**
45	1.27 g	1.31 f	1.19 i	**1.26 B**	1.32 g	1.38 f	1.24 i	**1.32 B**
60	1.41 c	1.45 ab	1.38 ef	**1.41 A**	1.47 c	1.51 ab	1.40 ef	**1.46 A**
75	1.43 bc	1.47 a	1.39 d	**1.43 A**	1.49 bc	1.53 a	1.44 d	**1.49 A**
Mean (B)	**1.31 B**	**1.36 A**	**1.26 C**		**1.37 B**	**1.42 A**	**1.30 C**	
				Curd diameter (cm)				
30	24.8 f	25.1 f	22.2 h	**24.1 C**	26.1 f	26.4 f	23.1 h	**25.2 C**
45	25.1 f	26.4 d	24.1 g	**25.2 B**	26.4 f	28.0 d	25.2 g	**26.5 B**
60	27.2 c	28.5 b	25.7 e	**27.1 A**	28.5 c	29.8 b	27.0 e	**28.4 A**
75	27.4 c	28.9 a	26.0 e	**27.4 A**	28.7 c	30.3 a	27.3 e	**28.8 A**
Mean (B)	**26.1 B**	**27.2 A**	**24.5 C**		**27.4 B**	**28.6 A**	**25.7 C**	
				Total yield (ton/feddan*)				
30	9.21 g	9.75 f	8.58 h	**9.18 C**	9.61 g	10.2 f	8.86 h	**9.54 C**
45	10.2 e	10.5 d	9.53 f	**10.1 B**	10.6 e	11.1 d	9.94 f	**10.5 B**
60	11.3 b	11.6 a	11.0 c	**11.3 A**	11.8 b	12.1 a	11.5 c	**11.8 A**
75	11.4 b	11.8 a	11.0 c	**11.4 A**	11.9 b	12.3 a	11.5 c	**11.9 A**
Mean (B)	**10.5 B**	**10.9 A**	**10.1 C**		**11.0 B**	**11.4 A**	**10.5 C**	

** 1 feddan = 4200 m^2 and 1 hectare = 2.4 feddan*

This is a factorial experiment from two factors: nitrogen rates (A), polyethylene mulch treatments (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant

Table 4. Effect of nitrogen rate and mulch on cauliflower leaves elemental content of N, P and K in the two studied seasons of 2012/2013 and 2013/2014

	2012/2013				2013/2014			
Nitrogen rate, kg/feddan (A)	**Polyethylene mulch treatments (B)**			**Mean (A)**	**Polyethylene mulch treatments (B)**			**Mean (A)**
	Black	**Transparent**	**Control**		**Black**	**Transparent**	**Control**	
				%N				
30	2.04 hi	2.12 g	1.99 i	**2.05 C**	2.08 i	2.16 g	2.05 i	**2.10 C**
45	2.11 g	2.14 f	2.06 h	**2.10 C**	2.16 g	2.20 fg	2.10 h	**2.15 C**
60	2.25 e	2.34 d	2.21 e	**2.27 B**	2.30 e	2.39 d	2.25 ef	**2.31 B**
75	3.06 b	3.23 a	2.43 c	**2.90 A**	3.09 b	3.26 a	2.45 c	**2.93 A**
Mean (B)	**2.37 B**	**2.46 A**	**2.17 C**		**2.41 B**	**2.51 A**	**2.21 C**	
				%P				
30	0.66 h	0.70 f	0.63 i	**0.66 D**	0.67 h	0.69 g	0.65 i	**0.67 D**
45	0.68 g	0.72 e	0.65 h	**0.68 C**	0.68 h	0.75 e	0.67 h	**0.70 C**
60	0.74 d	0.76 c	0.70 f	**0.73 B**	0.74 e	0.81 b	0.71 f	**0.75 B**
75	0.79 b	0.82 a	0.73 de	**0.78 A**	0.79 g	0.86 a	0.76 d	**0.80 A**
Mean (B)	**0.72 B**	**0.75 A**	**0.68 C**		**0.72 B**	**0.78 A**	**0.70 C**	
				%K				
30	3.62 f	3.70 e	3.56 g	**3.63 D**	3.55 g	3.63 f	3.46 h	**3.54 D**
45	3.69 e	3.79 c	3.60 f	**3.69 C**	3.58 g	3.70 e	3.49 h	**3.58 C**
60	3.75 d	3.85 b	3.71 e	**3.77 B**	3.68 e	3.77 c	3.64 f	**3.69 B**
75	3.87 b	3.97 a	3.77 cd	**3.87 A**	3.83 b	3.93 a	3.73 d	**3.83 A**
Mean (B)	**3.73 B**	**3.83 A**	**3.66 C**		**3.66 B**	**3.76 A**	**3.58 C**	

This is a factorial experiment from two factors: nitrogen rates (A), polyethylene mulch treatments (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant

Regarding the interaction effect between N and mulch treatments, the highest N, P and K contents were obtained in leaves of cauliflower applied with 75 kg N/feddan combined with transparent polyethylene mulch treatment followed by that of 75 kg N/feddan with black polyethylene mulch. The lowest N, P and K contents were obtained in leaves of plant in the control treatment with different N rates during both studied seasons.

Increased yield largely attributed to the increase in soil temperature due to application of mulch covers, which resulted in better soil environment activity around plants roots, led to increasing plant growth, and hence increasing nutrient absorption [10,27]. Optimal root zone temperature conditions allow for adequate root function including proper uptake of water and nutrients. Plant nutrient uptake, plant growth, and yield under mulch fit a quadratic relationship with root zone temperature [24].

3.5 Greenhouse Gas Emission from Nitrogen Fertilization and Impacts on Warming, Pollution and Plant Yield

The results presented in Table 5 and Fig. 2 showed that the N_2O and CO_2 emissions from different applied N rates more increased with increasing N rate from 30 to 75 kg/feddan. Values of N_2O emission varied from 2.90 to 3.78 kg/feddan; those of CO_2 emission were variable between 864 and 1127 kg/feddan. The highest yield (11558 kg/feddan) with low emission (89.9 CO_2 eq g/kg yield) was found with 60 kg N/feddan treatment. Similar results were obtained by other scientists [2].

High N fertilizer application rates resulted in higher N_2O emission and increase air pollution, therefore the vegetable industry potentially contributes a significant proportion of Australia's N_2O emission, with emissions likely to be relatively high on either 'per unit area' or 'per unit production' basis [30]. Changes in the application of fertilizer rate had a lower impact on emissions than on changes in the yield. If the application rate of fertilizer increased by 20%, GHG emission per hectare will increase by 10%. On the other hand, if the application rate of fertilizer decreased by 20%, GHG emission per hectare will decrease by 10% [31]. Numerous field studies conducted on N input gradients in row-crop agriculture and found that emissions of N_2O positively correlated well with fertilizer N rate [32-34]. Nitrogen fertilizer application rate may reduce N_2O and CO_2 emissions substantially where N fertilizer is applied at rates greater than the economic optimum rate. Applying polyethylene mulch to minimize soil wetness can reduce N_2O emissions [11,12,22,27].

Table 5. Emissions for different applied nitrogen rates

N rate kg/feddan*	Total N_2O kg/feddan*	Total CO_2 eq kg/feddan*	Yield kg	CO_2 eq g/kg yield
30	2.90	864	9362	92.3
45	3.19	952	10300	92.4
60	3.49	1040	11558	89.9
75	3.78	1127	11647	96.8

** feddan = 4200 m^2 and hectare = 2.4 feddan*

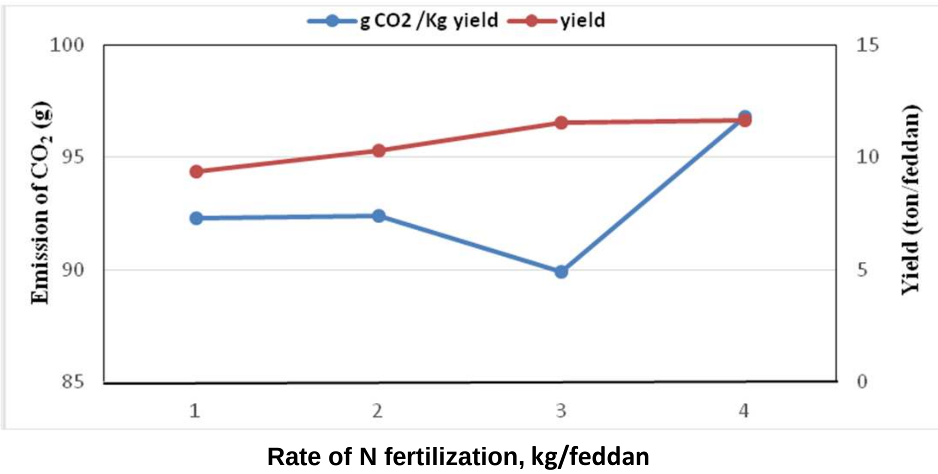

Fig. 2. CO_2 emission and total yield under different nitrogen rates (1=30, 2=45, 3=60 and 4=75 kg/feddan)

4. CONCLUSION

The present investigation revealed that, mulch can improve plant growth and yield of cauliflower when compared with bare soil. Using polyethylene mulches, especially the transparent and black, being useful. Increase in the rate of N application up to 60 kg/feddan is recommended for larger and heavy cauliflower curds under field conditions. Use of 60 kg N/feddan with transparent polyethylene mulch is useful for increasing the yield and low N_2O and CO_2 emissions. N_2O is an important GHG that contributes to climate change. Because it has a long atmospheric lifetime (over 100 years) and is about 300 times better at trapping heat than is CO_2, even small emissions of N_2O affect the climate. Improving the management of N fertilizer for field crops can improve nitrogen use efficiency (saving farmers money) and reduce N_2O emission (helping the climate).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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