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RESEARCH ARTICLE

Response of durum wheat (*Triticum durum*, L.) to different combinations of chemical nitrogen fertilizer levels and the red yeast as a biofertilizer

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Abstract

The aim of this research was to assess the impact of different combinations of chemical nitrogen fertilizer levels and red yeast as a biofertilizer (F_1,100 kg N+ red yeast; F_2, 75kg N+ red yeast; F_3,50kg N+ red yeast;F_4, 25kg N+ red yeast; F_5, unfertilized N+ red yeast and F_6,100kg N without red yeast) on microbial biomass carbon and nitrogen, growth characteristics, yield and its components as well as harvest index of four durum wheat cultivars (V_1, Beni-swif 5; V_2, Beni-swif 1; V_3, Sohag4; V_4, Sohag5). Results confirmed that, different wheat cultivars exhibited a significant effect on most studied traits in both seasons. V_1 surpassed all tested cultivars for most studied traits followed by V2, meanwhile, V4 ranked the last one for most traits in both seasons. The combination of all chemical nitrogen fertilizers with red yeast possessed a highly significant effect on all studied characteristics. Significant interactions were recorded between cultivars and different combinations of yeast and nitrogen fertilizer levels on wheat yield and its components during both seasons, $V_2 \times F_2$ and $V_2 \times F_1$ obtained the greatest biological yield of 7.89 and 7.40 ton/fed. and grain yield of 20.75 and 20.49 ardab/fed in the first and second seasons, respectively. Grain yield (ardab/fed.) was highly positive and significantly correlated with all studied traits in both seasons. In conclusion, applying red yeast as a promising biofertilizer with different chemical nitrogen fertilizer rates could be recommended because it significantly increased the microbial biomass and, achieved a highly significant wheat yield, while reducing chemical fertilizers consumption.

Keywords: Biofertilizers; Durum wheat; Nitrogen; Microbial biomass; Red yeast.

1. Introduction

Wheat is the most important cereal crop which ranks first among the cereal crops in the world, accounting for 30% of all cereal food worldwide and major food for over one third of world people that provides about 20% of the total food calories directly or indirectly for humans Namvar and Khandan (2013). In Egypt, increasing wheat production is an essential national target to fill the gap between production which reached 9 million tons and consumption which increased to 16 million tons FAO Statistics Division (2019).

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At the present time, due to the highly fertile alluvial soils and availability of Nile water for irrigation, wheat productivity in Egypt is the highest in Africa (Yigezu *et al.*, 2021). For example, the average wheat production in the country is about 6.7 tons/ha which is much higher than the African average of 2.6 tons/ha. However, due to the rapid population growth, the country is under pressure to reclaim new lands for agriculture and thus increase

the pressure on limited arable soils and water supply. Another national challenge that Egypt is currently facing is that due to the intensive chemical fertilizer application, 35% of agricultural land suffers from pollution, salinity and, poor biodiversity which reduces the productive capacity of the fertile alluvial soils (FAO Statistics Division, 2019). Increasing the yield of wheat (*Triticum aestivum* L.) is a vital national goal to meet the growing food needs of the Egyptian population, while wheat is one of the three major cereal crops (Niel, 2021). The Egyptian government and scholars have paid great attention and efforts to increase wheat productivity to narrow the wheat security gap in production and consumption by increasing water productivity, fertilizer use efficiency, unit productivity area and, increasing the cultivated area (FAO Statistics Division, 2019; Niel, 2021; Yigezu *et al*., 2021).

Increasing wheat production per unit area can be achieved by breeding and cultivating the promising wheat cultivars and applying the optimum cultural practices such as suitable fertilizer. There was a significant difference among cultivars (Zaki *et al.*, 2016; Yasser *et al.*, 2018). Many research demonstrated that wheat cultivars differed significantly for growth, yield, and yield components (Hasanpour *et al.*, 2012; Mohamed *et al.*, 2013; Taher *et al.*, 2013; Nabila *et al.*, 2015; Bizuwork and Yibekal, 2020).

Nitrogen is one of the essential nutrients for plants and its practical management as the major element for intensive plant production is an important aspect. Many investigators reported the meliorating effect of N-fertilizers on wheat yield and its components, No. of spikes/m^2, grain yield/fad., and harvest index (Abdul Galil *et al.*, 2003) plant height significantly affected by N levels, the tallest plants 89.40 cm are noted in 92 kg N/ha^{-1} (Bizuwork and Yibekal, 2020) grain number/spike, spike number/ m^2, 1000-grain weight, and grain yield/fad. (Hafez, 2007); spike number/m^2, grain number/ spike, grain weight/spike, 1000-grain weight, and grain yield/fad. (Amin *et al.*, 2011; Farag and El-Khawaga, 2013). The steadily increasing prices of chemical fertilizers, especially nitrogenous fertilizers, and severe negative environmental impacts on soil and water, have led to the development of alternative strategies, use of biological fertilizers today is considered to limit the use of mineral fertilizers (El-Sirafy *et al.*, 2006). Application of biofertilizers decreases agricultural costs, maximizing crop yield due to providing them with an available nutritive elements and growth promoting substances (Metin *et al.*, 2010). The use of bio-fertilizers could reduce amount of chemical fertilizer input by increasing the efficiency of nutrient availability and other plant growth-promoting activities. Bio-fertilizers hold a promise to balance many drawbacks of the conventional chemical-based technology and could recuperate healthy farming practices and bio-farming (Minaxi *et al*., 2013; Amira *et al.*, 2016; Moustafa *et al.*, 2017). Using of either organic or biofertilizer are considered a safe alternative for chemical fertilizers, which cause environmental pollution when they are used extensively Ozturk *et al.*, 2012; Abd El-Lateef, 2018). Biofertilizers inoculation significantly increased most growth and yield parameters, yeast had superiority on Azotobacter. Moreover, mixed inoculums, generally, had more favorable effect on the majority of studied parameters than single inoculants (El-Sirafy *et al.*, 2006; Bahrani and Pourreza, 2010; Nawab *et al*., 2006; Amal *et al.*, 2011). Many authors achieved the positive effect of bio-fertilizer on wheat (Singh and Prasad, 2011; Amira *et al.*, 2016; Abd El-Lateef, 2018).

Little information is available on the effect of red yeast application as a biofertilizer in combination with different application rates of inorganic nitrogen fertilizer on the productivity, growth, and grain quality characteristics of different wheat cultivars. Investigating new yeasts as biofertilizers expands our knowledge about their approached mechanisms due to their productivity of bioactive chemical compounds that improve soil quality and enhance plant growth and quality characteristics. In addition to its role in promoting plant growth and quality, yeast as a biofertilizer can act in unison as biocontrol agents in the soil rhizosphere (Abou-Zeed, *et al.*, 2014). Red yeast

(*Xanthophyllomyces dendrorhous)* (formerly Phaffia) is considered as a new promising plant growth-promoting yeast for different crops. Recently, it became a positive alternative to chemical fertilizers safely used for humans, animals, and the environment (Moustafa *et al*., 2017). Previous studies clarified the effect of yeast soil application as a biofertilizer on vegetative growth parameters owing to its affluence in tryptophan which is a precursor of IAA (Indole acetic acid) and on flower trigger because of increasing carbohydrate accumulation (Abou-Zeed, *et al.*, 2014; Yasser *et al.*, 2018). Moreover, significant changes in soil microbial biomass C and N have been explored from prior research studies during the cropping seasons and under different soil fertilization systems and techniques (Haddad *et al*., 2013). Generally, microbial biomass can be utilized for soil quality assessments in situations involving different crop genotypes and different fertilization practices (Moustafa *et al*., 2018). The main objectives of this study were to evaluate the influence of combined chemical nitrogen fertilizer and red yeast as a biofertilizer on microbial biomass and productivity of four durum wheat cultivars under middle Egypt conditions.

2. Materials and methods

2.1. Soil used

The soil of the experimental location had a clay loam texture. Preceding to the inception of the field trial, clay loam soil detailed in Table 1 was collected, air dried, sieved to < 2.0 mm, and composite sub-samples were used to determine the basic soil physical and chemical properties according to Avery and Bascomb (1982).

Table 1. Physical and chemical properties of the experimental soil.

Soil chemical properties	Value	Soil physical properties	Value
pH (1:2.5 water)	7.7	F.C. %	42.45
$CaCO_3$ (g kg^{-1})	17.9	PWP %	13.78
CEC (cmol$_c$ kg^{-1})	37.87	WHC %	48.76
EC (dS m^{-1} at 25 ^{0}C)	1.35	A. V. (F.C. – PWP) %	28.67
OM (g kg $^{-1}$)	28.61	A. V. (WHC-PWP) %	34.98
Total N (g kg $^{-1}$)	1.29	Sand %	28.9
Total C/N ratio	22.17	Silt %	32.8
SOC (g kg $^{-1}$)	18.48	Clay %	38.3
Organic N (g kg $^{-1}$)	0.76	Soil texture	Clay loam
Organic C/N ratio	24.31		
Mineral N (mg kg $^{-1}$)	58.46		
Total P (g kg $^{-1}$)	0.56		
Available P (mg kg $^{-1}$)	13.11		
Total K (g kg $^{-1}$)	4.37		

2.2. Experimental design

Two field experiments were conducted at the Experimental Farm, Faculty of Agriculture, Minia University (latitude of 28º18'16"N and longitude of 30º34'38"E), EL-Minia Governorate, Egypt, during two successive winter seasons of 2018/2019 and 2019/2020. The scientific aim of this research was to assess the impacts of different combinations of chemical nitrogen fertilizer and red yeast as a biofertilizer i.e., (F_1, 100 kg N+ red yeast; F_2, 75kg N+ red yeast; F_3, 50kg N+ red yeast; F_4, 25kg N+ red yeast; F_5, unfertilized N+ red yeast; F_6,100kg N without red yeast), on microbial biomass C and N, growth characters, yield, and its components as well as harvest index of four durum wheat cultivars (V_1, Beni-swif 5; V_2, Beni-swif 1; V_3, Sohag4; V_4, Sohag5). A randomized complete block design (RCBD) was used, in a split plot arrangement and replicated three times. Wheat cultivars were assigned to the main plots. The sub-plots were devoted to the fertilization system, each sub-plot area was 10.5 m^2 (3.5 × 3 m), included 20 rows, 15 cm apart. The preceding crop was maize in both seasons, wheat grains were hand drilled in rows at the rate of 400 seeds/m^2. The mechanical and chemical analysis of the experimental soil was done before the sowing according to (Avery and Bascomb, 1982), as shown in Table 1. The sowing dates were 20th and 21st of November in the first and second seasons, respectively. The harvesting was done on 25th and 27th of April in both seasons, respectively, Ammonium nitrate (33.5% N) as chemical N fertilizer was used, N-fertilizer was splited into two doses, the first was applied 35 days after sowing (DAS), just before the 1st irrigation, the second dose was applied 48 DAS. The amounts of the commercial fertilizer were calculated according to each nitrogen level in different fertilization system. Calcium superphosphate of 15.5% P_2O_5 at the rate of 100 kg/fed and potassium at the rate of 25 kg K_2O/fed as potassium sulfate (48% K_2O) were added at seed bed preparation. The treated plots were inoculated with *Xanthophyllomyces dendrorhous* Golubev (ATCC 96594): [VKM Y-2793] supplied by American Type Culture Collection (ATCC) Manassas, VA 20108 USA of 35 days after sowing (DAS), just before the 1st irrigation, the second dose was applied 48 DAS. The inoculants contained a minimum of 3 × 10^9 mL^{-1} viable cells (Moustafa *et al.,* 2017).

2.3. Microbial biomass C and N:

Microbial biomass carbon (C_{mic}) and nitrogen (N_{mic}) were determined on field moist samples using the chloroform fumigation-extraction procedure (Vance *et al.,* 1987). In this technique, 5 g of each sampled soil was weighed into 50-mL glass vials and fumigation was carried out for 24 hours at 25°C. Extraction was thereafter made with 0.5 M potassium sulfate solution (K_2SO_4; 5 mL g^{-1} soil) and placed on a vacillating shaker for 30 minutes at 200 rev min^{-1} and the suspension filtered through a Whatman 42 filter paper. Controls were not fumigated. An aliquot (5 mL) of each sample extract was then analyzed for C_{mic} as described by Vance *et al.* (1987), while N_{mic} was determined using the Kjeldahl digestion procedure (Brookes *et al*., 1985). C_{mic} and N_{mic} were then estimated by the differences between fumigated and unfumigated samples and dividing with *k*-factors of 0.45 for C_{mic} (Vance *et al.,* 1987) and 0.54 for N_{mic} (Brooks *et al.,* 1985).

2.4. The recorded data

At harvest, ten inner rows from each plot were harvested and ten plants were taken randomly to estimate the following data:

1- Plant height(cm.): measured at harvest from soil surface to the tip of the spike of the main stem.

2- Number of tillers/plants.

3- Spike length (cm.): measured at harvest from the main stems, which were used for estimation of plant height.

4- Number of spikelets/spikes: determined as number of fertile and sterile spikelets of ten spikes from each plot at harvest.

5- Number of grains /spikes: estimated on the basis of 10 spikes randomly collected from each plot.

6- 1000 grain weight (g.): determined from the three random samples each contained 1000 grains, taken from each plot, then the main of grain index was recorded.

7- Biological yield (ton/fed.): ten inner rows of 5.25m^2 of each plot harvested and weighted in kg., then transformed into ton /fed.

8- Grain yield(ardab/fed.): according to harvested ten inner rows of 5.25m^2 of each plot in kg., then transformed into ton /fed.

9- Straw yield (ton /fed.): measured by subtracting grain yield (ton/fed.) from biological yield (ton/ fed.).

10- Harvest Index: was calculated using the following formula:

Harvest Index= (grain yield/biological yield) ×100.

2.5. Statistical analysis

All data were statistically analyzed according to technique of analysis of variance (ANOVA) for the split- plot design with three replications by means of "MSTAT-C" computer software package according to Gomez and Gomez (1984), and least significant differences (L.S.D.) test was used to compare treatment means at 5% level of probability.

3. Results and Discussion

3.1 Effect of durum wheat cultivars on growth, yield, and its components

3.1.1. Effect of durum wheat cultivars on growth characters

Data presented in Table (2) showed that durum wheat cultivars had a significant effect on No. of tillers/plant in the second season only. Beni-swif1(v_2) gave the highest value for this trait of 3.76 followed by Sohag4 (v_3) of 3.63. This result may be due to the genetic behavior adaptation with environment conditions. These results are in agreement with those reported by (Hasanpour *et al.,* 2012; Zaki *et al.,* 2012; Yasser *et al.,* 2018; Kasim *et al.,* 2021).

3.1.2. Effect of durum wheat cultivars on yield and its components characters

Regarding the effect of durum wheat cultivars on yield and yield attributes characters, spike length (cm.), grain yield (ardab/fed.) and straw yield (ton/fed.) had highly significant affected in both seasons, as well as No. of spikelets/spike, No. of grains/spike and 1000 grain weight in the 1st one. Moreover, cultivars differed highly significantly for biological yield (ton/fed.) in the 2nd season, as shown in Table (2). Beni-swif 5(v_1) surpassed all tested cultivars for spike length of 8.73 and 9.75cm. in the first and second seasons, respectively, and for No. of spikelets/spike of 17.09, No. of grains/spike of 50.48 and 1000 grain weight of 55.82 in the 1st one, as well as biological yield of 5.65 ton/fed., grain yield of 15. 95 ardab/fed. and straw yield of 3.26 ton/fed. in the second season, followed by Beni-swif 1(v_2) for all previous traits. Meanwhile, Beni-swif 1(v_2) recorded greatest grain yield of 17.53 ardab/fed., straw yield of 4.25 ton/fed. in the 1st seasons. The differences among wheat cultivars under study could be attributed to the genetic make-up and their response to the environmental conditions prevailing during its growth. Similar trend of results was achieved by (Mohamed *et al.,* 2013; Taher *et al.,* 2013; Yasser *et al.,* 2018; Bizuwork and Yibekal, 2020).

3.2. Effect of different combinations of chemical nitrogen fertilizer and yeast biofertilizer on growth, yield and its components

3.2.1. Effect of chemical nitrogen fertilizer and yeast biofertilizer on growth characters

The results involved in Table (3) revealed that nitrogen and bio-fertilization treatments possessed highly significant effect on growth characteristics i.e., plant height and No. of tillers/plant. F_1 recorded the highest values of no. of tillers/plant of 4.17 and 4.38 in the first and second seasons, respectively, as well as plant height of 101.04cm in the 2nd one, meanwhile the tallest plants of 103.85cm were detected by F_3 in the first season. On contrary the lowest values for the previous growth traits were recorded by F_5. These results may be due to yeast as a bio - fertilizer was not as effective as nitrogen chemical fertilizer on growth of wheat. High nitrogen demand of wheat needs readily available nutrient in peak-demanding stages, which improvement of growth and some yield attributes such as the spike length and 1000-grain weight, which in turn increase in the grain yield/ plant, consequently grain yield/fad. This supports the findings of (El-Sirafy *et al.,* 2006; Metin *et al.,* 2010; Ozturk *et al.,* 2012; Namvar and Khandan, 2013; Rajasekaran *et al.,* 2015; Yasser *et al.*, 2018).

Table 2. Effect of durum wheat cultivars (*Triticum durum* L.) on growth yield, and its components at harvest in 2018/2019 and 2019/2020 seasons.

Characters / Treatments		Plant height (cm.)	No. of tillers/plant	Spike length (cm.)	No. of spikelets / spike	No. of grains/spike	1000 grain weight (g)	Biological Yield (ton/fed.)	Grain yield (ardab/fed.)	Straw yield (ton/fed.)	Harvest Index %
2018 /2019											
A: durum wheat cultivars	V1	99.62	3.46	8.73	17.09	50.48	55.82	6.56	16.81	4.04	40.79
	V2	99.75	3.48	8.64	16.40	48.45	55.09	6.88	17.53	4.25	40.53
	V3	99.24	3.46	6.75	14.20	41.98	47.71	6.28	16.00	3.88	39.19
	V4	99.54	3.48	6.32	14.77	43.59	48.08	5.67	14.38	3.52	39.78
F-test		NS	NS	**	**	**	**	NS	**	**	NS
LSD at 0.05		-	-	0.94	0.01	0.10	2.93	-	0.25	0.04	-
2019 /2020											
A: durum wheat cultivars	V1	93.64	3.62	9.75	17.05	50.71	58.41	5.65	15.95	3.26	42.40
	V2	94.12	3.76	9.12	16.90	47.22	58.58	5.59	15.82	3.22	42.67
	V3	93.95	3.63	7.75	14.17	45.94	53.49	5.44	15.45	3.12	42.71
	V4	94.10	3.56	6.67	13.50	43.70	48.43	5.03	14.38	2.88	4299
F-test		NS	*	**	NS	NS	NS	**	**	**	NS
LSD at 0.05		-	0.11	0.24	-	-	-	0.02	0.24	0.01	-
V:				V1: Beni-swif 5		v2: Beni-swif 1		v3: Sohag4	v4: Sohag5		

3.2.2. Effect of some chemical nitrogen fertilizer and yeast bio-fertilizer on yield and its components

The impacts of different combinations of chemical nitrogen fertilizer and yeast bio-fertilizer on yield and its components were recorded in Table (3). All yield and its components i.e., spike length, No. of spikelets /spike, No. of grains/spike, 1000 grain weight, biological yield, grain yield, straw yield and harvest index were affected highly significant among different combinations of chemical N fertilizer and yeast bio-fertilization rates. F_1 was superior other than the fertilizer combinations for spike length (8.49 and 9.38 cm.), 1000 grain weight (55.09 and 59.01 g), biological yield (7.42 and 6.79ton/fed.), grain yield (19.51 and 18.92 ardab/fed.) and straw yield (4.50 and 3.95ton/fed.) in the first and second seasons respectively, and for No. of spikelets /spike of 17.19 and No. of grains/spike of 50.64 in the second season. While F_2 outperformed for No. of spikelets /spike of 17.09 and of No. grains/spike of 50.31 in the 1st season. Meanwhile, the greatest harvest index values of 42.15 % and 43.82% were obtained by F_6 and F_5 in the 1st and 2nd seasons, respectively. These results are in agreement with those reported by (El-Sirafy *et al.,* 2006; Abd El-Lateef, 2018; Manal *et al.*, 2019; Bizuwork and Yibekal 2020; Kasim *et al.,* 2021; Niel, 2021). Concerning the effect of yeast bio-fertilization alone on yield and its components, it could be concluded that the lowest values for all studied traits except harvest index were recorded by F_5 and F_6 bio-fertilizer combinations. In spite of F_1

was superior other than the fertilizer combinations for most studied traits, it could be concluded that F_2 increased 1000 grain weight by 14.58 and 17.51%; biological yield by35.35 and 54.13% ; grain yield/plant by 45.69 and 48.10% and straw yield by29.19 and 58.30% in the 1st and 2nd seasons, respectively as compared with F_6 with no significant differences with F_1. Thus, F_2 surpassed the other nitrogen and bio-fertilization combinations for decreased total costs, pollution and maximized productivity and net profit per fed. This may be due to the role of bio-fertilization (red yeast application) in enhancement of physical and chemical soil properties and additional amount of nitrogen made available by biological fixation of nitrogen by organism, this nitrogen helps in improve growth and increase photosynthesis rate resulting in the accumulation of more dry matter by crop (Kasim *et al.*, 2021; Niel, 2021). These results are in the same trend with those obtained by (Mostafa *et al.*, 2017; Abd El-Lateef, 2018; Yasser *et al.*, 2018).

Table 3. Effect of some chemical nitrogen fertilizer and yeast bio-fertilizer on growth yield, and yield component at harvest in 2018/2019 and 2019/2020 seasons.

Characters / Treatments		Plant height (cm.)	No. of tillers/plant	Spike length (cm.)	No. of spikelets/spike	No. of grains/spike	1000 grain weight(g.)	Biological Yield (ton/fed.)	Grain yield (ardab/fed.)	Straw yield (ton/fed.)	Harvest Index%
						2018 /2019					
B: Fertilizer treatments	F1	102.34	4.17	8.49	16.59	48.92	55.09	7.42	19.51	4.50	39.91
	F2	103.18	3.76	8.29	17.06	50.31	54.70	7.39	19.42	4.47	37.91
	F3	103.85	3.66	8.08	16.75	49.32	53.81	7.06	18.41	4.30	38.26
	F4	100.64	3.35	7.31	15.03	44.53	50.64	5.94	14.63	3.75	42.02
	F5	91.78	2.52	6.49	14.14	41.89	48.06	4.82	11.78	3.05	40.17
	F6	95.45	3.34	6.99	14.10	41.78	47.74	5.46	13.33	3.46	42.15
F-test		**	**	**	**	**	**	**	**	**	**
LSD at0.05		1.75	0.11	0.34	0.14	0.33	2.52	0.15	0.28	0.14	2.22
						2019 /2020					
B: Fertilizer treatments	F1	101.04	4.38	9.38	17.19	50.64	59.01	6.79	18.92	3.95	41.74
	F2	99.60	4.04	9.19	16.91	49.60	58.85	6.72	18.75	3.91	41.77
	F3	95.99	4.26	8.83	16.40	49.89	55.02	5.94	16.76	3.43	42.20
	F4	90.89	3.00	7.86	14.53	46.12	54.02	4.72	13.53	2.69	43.06
	F5	85.43	2.86	7.28	13.48	41.53	51.39	4.04	11.79	2.27	43.82
	F6	90.76	3.33	7.39	13.91	43.57	50.08	4.36	12.66	2.47	43.57
F-test		**	**	**	**	**	**	**	**	**	**
LSD at0.05		0.74	0.23	0.30	0.61	0.38	0.36	0.25	1.	0.07	1.32
F:		F1=100 kg N+ red yeast, f2= 75kg N+ red yeast, f3=50kg N+ red yeast, f4= 25kg N+ red yeast, f5= unfertilized N+ red yeast, f6=100kg N without red yeast									

3.3. Effect of the interaction between cultivars and different combinations of chemical nitrogen and yeast bio-fertilizer on growth, yield and yield component

3.3.1. Effect of the interaction between cultivars and different combinations of chemical nitrogen fertilizer and yeast bio-fertilizer on growth characters

Data presented in Tables (4 and 5) show the effect of interaction between cultivars and different chemical nitrogen fertilizer and yeast bio-fertilization combinations on growth, yield and yield component in the 1st and 2nd seasons. The presented data in Table (4) indicated that the interaction between durum wheat cultivars and different combinations of chemical nitrogen fertilizer and yeast bio-fertilizer did not show significant effect on plant height and No. of tillers/plant in both seasons. our findings are in conflicting with obtained by those, (Hassanein *et al.,* 2018).

3.3.2. Effect of the interaction between cultivars and some chemical nitrogen and yeast bio-fertilization combinations on yield and its components

Influence of the interaction between durum cultivars and some nitrogen and bio-fertilization combinations was highly significant upon No. of grains/spike and biological yield in both seasons, spike length, No. of spikelets /spike and grain yield in the first season as well as, 1000 grain weight and straw yield in the second season, as shown in Tables (4 and 5). ($V_{1\times}$ $F_{1)}$ gave the tallest spike of 10.53cm., highest No. of spikelets/spike of 18.77 and No. of grains/spike of 55.33 in the 1st season, however (V_2×F_2) recorded highest biological yield of 7.89 ton/fed., grain yield of 20.75 ardab/fed. in the first season, 1000 grain weight of 61.66g. in the second season. Meanwhile, (V_2 × F_1) surpassed all tested cultivar for biological yield of 7.40 ton/fed. and straw yield of 4.33 ton/fed. in the second season. The greatest No. of grain/spike of 55.63 was obtained by (V_2 × F_1) in the second season. The finding results of (Hassanein *et al.,* 2018) supported our findings.

Table 4. Effect of the interaction between cultivars and different combinations of chemical nitrogen and yeast bio-fertilizer on plant height, No. of tillers/plant, spike length, No. of spikelets/spike and No. of grains/spike at harvest in 2018/2019 and 2019 /2020 seasons.

Characters / Treatments		Plant height (cm.)		No. of tillers/plant		Spike length (cm.)		No. of spikelets/spike		No. of grains/spike	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
C: Interaction A×B	V1×F1	102.40	100.76	4.15	4.29	10.53	10.52	18.77	19.41	55.33	54.63
	V1×F2	103.13	99.63	3.76	3.80	10.36	10.55	18.00	18.82	53.06	52.56
	V1×F3	104.21	85.43	3.66	4.36	9.53	10.48	17.65	17.90	52.03	51.63
	V1×F4	100.62	90.40	3.35	3.16	7.65	9.36	15.79	16.41	46.76	48.90
	V1×F5	91.88	85.40	2.50	2.91	6.73	8.75	15.69	14.33	46.47	47.77
	V1×F6	95.50	90.24	3.34	3.22	7.56	8.83	16.62	15.43	49.21	48.77
	V2×F1	102.41	101.16	4.23	4.52	9.86	10.55	17.77	18.65	52.38	51.66
	V2×F2	103.41	99.89	3.76	4.21	9.16	10.05	17.60	18.57	51.88	49.56
	V2×F3	104.36	96.45	3.66	4.30	8.66	9.44	18.70	17.90	55.13	55.63
	V2×F4	100.27	91.06	3.36	3.04	8.53	8.72	16.19	15.64	47.94	46.81
	V2×F5	91.97	85.33	2.51	2.92	7.76	7.86	14.30	15.20	42.37	37.87
	V2×F6	96.06	90.81	3.35	3.58	7.86	8.07	13.84	15.44	41.01	41.83
	V3×F1	101.54	101.77	4.09	4.33	6.84	8.72	14.79	15.85	43.59	48.67
	V3×F2	102.96	98.69	3.76	4.20	7.10	8.48	15.90	15.75	46.87	48.78
	V3×F3	103.44	96.18	3.67	4.15	6.95	8.15	14.70	15.46	43.33	46.59
	V3×F4	101.19	91.14	3.36	2.99	6.93	7.56	13.56	13.42	40.18	44.87
	V3×F5	91.59	85.07	2.53	2.87	6.01	7.05	13.09	12.21	38.80	42.91
	V3×F6	94.70	90.84	3.36	3.26	6.65	6.56	13.19	12.34	39.09	43.87
	V4×F1	103.02	100.48	4.22	4.37	6.73	7.75	15.05	14.85	44.36	47.63
	V4×F2	103.22	100.20	3.77	3.94	6.53	7.68	16.77	14.52	49.43	47.53
	V4×F3	103.37	95.92	3.68	4.22	7.18	7.25	15.98	14.35	46.81	45.73
	V4×F4	100.46	90.94	3.34	2.83	6.12	5.79	14.59	12.64	43.22	43.91
	V4×F5	91.67	85.92	2.53	2.75	5.46	5.44	13.47	12.19	39.92	37.60
	V4×F6	95.53	91.13	3.36	3.25	5.89	6.09	12.76	12.44	37.82	39.81
F-test		NS	NS	NS	NS	**	NS	**	NS	**	**
LSD at0.05		-	-	-	-	1.05	-	0.26	-	0.61	0.70

Concerning the effect of interaction between cultivars and different combinations of chemical nitrogen and yeast bio-fertilizer, results in Tables (4 and5) indicated that (V_4 ×F_5) recorded the lowest values of spike length of 5.46cm. and grain yield of 10.80 ardab/fed. in the 1st season, No. of grains/spike of 37.60 and straw yield of 2.20 ton/fed. in the 2nd season, as well as biological yield of 4.42 and 3.91ton/fed. in the 1st and 2nd seasons, respectively.

Table 5. Effect of the interaction between cultivars and different combinations of chemical nitrogen and yeast bio-fertilizer on 1000 grain weight, biological yield, grain yield, straw yield and harvest index at harvest in 2018/2019 and 2019 /2020 seasons.

Characters / Treatments		1000 grain weight		Biological Yield (ton/fed.)		Grain yield (ardab/fed.)		Straw yield (ton/fed.)		Harvest Index	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
C: Interaction A×B	V1×F1	58.24	60.16	7.69	6.90	20.22	19.21	4.66	4.02	40.41	41.67
	V1×F2	57.51	59.09	7.86	7.00	20.67	19.47	4.76	4.08	38.12	41.62
	V1×F3	56.69	59.19	7.49	5.90	19.70	16.66	4.54	3.40	40.43	42.22
	V1×F4	55.01	57.11	6.09	5.12	15.33	14.32	3.79	2.98	43.15	41.94
	V1×F5	54.58	57.81	4.78	4.23	11.68	12.31	3.03	2.39	39.36	43.66
	V1×F6	52.86	57.11	5.42	4.76	13.24	13.74	3.43	2.70	43.27	43.29
	V2×F1	57.86	61.39	7.86	7.40	20.67	20.49	4.76	4.33	41.41	41.45
	V2×F2	57.86	61.66	7.89	7.27	20.75	20.16	4.78	4.25	39.45	41.50
	V2×F3	57.03	58.12	7.69	5.80	20.22	16.40	4.66	3.34	38.78	42.29
	V2×F4	56.21	58.14	6.19	5.03	15.13	14.46	3.92	2.87	42.06	43.13
	V2×F5	49.92	55.92	5.39	3.96	13.17	11.58	3.42	2.23	39.67	43.88
	V2×F6	51.68	56.24	6.23	4.06	15.22	11.85	3.95	2.29	41.80	43.80
	V3×F1	52.65	57.12	7.26	6.57	19.10	18.37	4.40	3.82	38.46	41.83
	V3×F2	50.43	58.36	7.19	6.40	18.91	17.93	4.36	3.71	38.07	41.92
	V3×F3	48.68	57.69	6.85	6.29	18.02	17.65	4.15	3.64	36.11	41.99
	V3×F4	46.06	54.83	6.09	4.76	14.88	13.74	3.86	2.70	41.39	43.29
	V3×F5	43.73	47.01	4.69	4.04	11.46	11.80	2.97	2.27	39.35	43.81
	V3×F6	44.73	45.95	5.59	4.56	13.66	13.20	3.54	2.58	41.75	43.42
	V4×F1	51.62	57.37	6.86	6.27	18.05	17.60	4.16	3.63	39.36	42.00
	V4×F2	53.00	56.29	6.59	6.20	17.34	17.42	3.99	3.59	36.01	42.04
	V4×F3	52.83	45.09	6.19	5.77	15.69	16.32	3.84	3.32	37.70	42.31
	V4×F4	45.29	46.01	5.39	3.97	13.17	11.61	3.42	2.23	41.49	43.88
	V4×F5	44.02	44.82	4.42	3.91	10.80	11.45	2.80	2.20	42.33	43.93
	V4×F6	41.70	41.04	4.59	4.06	11.21	11.85	2.91	2.29	41.79	43.80
F-test		NS	**	**	**	**	NS	NS	**	NS	NS
LSD at 0.05		-	0.67	0.30	0.47	0.54	-	-	0.13	-	-

These results may be due to the differences between four tested cultivars in growth custom and response of each cultivar to adapt with environmental conditions which was controlled by genetic factors and positively responded to nitrogen fertilizer. In addition, the bio-fertilizer with *Xanthophyllomyces dendrorhous* (red yeast) enhancing soil biological activity, which plays a significant role in regulating the dynamics of organic matter decomposition and the availability of plant nutrients and in increasing nitrogen fixer. These results are in good line with those mentioned by (Atia and Aly, 1998; Kader *et al.*,2002; Nawab *et al.*,2006; Bahrani and Pourreza,2010; Metin *et al.*,2010; Abd El-Lattief,2016; Mostafa *et al*.,2017; Yasser *et al.*,2018).

3.4. Effect on microbial biomass carbon and nitrogen

Microbial biomass C and N are the most important biochemical pools that affect the N mineralization process in soils. They are considered as an indicator of the process of ammonification under different soil conditions (Haddad *et al.,* 2013). Data presented in Table (6) show the effect of the combination of chemical nitrogen fertilizer levels and the red yeast on the microbial biomass C and N at two successive seasons. Generally, results confirmed that microbial biomass carbon (C_{mic}) significantly increased when using nitrogen fertilizer at 75% plus red yeast with Beni-swif 5 and 1 cultivar followed by using nitrogen fertilizer at 25% plus red yeast with the above-mentioned cultivars. On the other hand, microbial biomass nitrogen (N_{mic}) significantly increased when using nitrogen fertilizer at 100% only without red yeast. This is maybe a result of the availability of nitrogen increased after inorganic N fertilizers additions and thus microorganisms immobilized N (Wang *et al*., 2008). Moreover, this is completely matched with the results obtained by Abd El-Azeim *et al.* (2020) who reported that, incorporated fertilization system recorded major levels of N_{mic} and C_{mic} in comparison to inorganic fertilizers even though applied at lower rates. It is, accordingly, important for soils under any cropping system to balance organic and inorganic fertilizers that promote soil microbial activity and soil health.

Table 6. Effect of combination of chemical nitrogen fertilizer levels and the red yeast on the microbial biomass C and N at two successive seasons.

Cultivars/Treatments		Microbial biomass C (C_{mic})		Microbial biomass N (N_{mic})	
		2018/2019	2019/2020	2018/2019	2019/2020
V1	F1	260	283	98	103
	F2	520	570	83	95
	F3	355	415	60	66
	F4	360	380	18	24
	F5	300	310	49	70
	F6	213	240	106	121
L.S.D 0.05		32.14	29.94	9.07	2.91
V2	F1	250	292	104	112
	F2	480	582	87	107
	F3	370	400	72	80
	F4	390	418	30	29
	F5	315	330	60	80
	F6	230	280	109	115
L.S.D 0.05		21.14	23.18	8.52	6.14
V3	F1	210	218	98	106
	F2	408	490	85	90
	F3	310	350	68	84
	F4	350	390	28	41
	F5	260	258	40	60
	F6	206	194	93	93
L.S.D 0.05		18.91	19.14	12.60	5.21
V4	F1	180	213	87	100
	F2	390	412	76	86
	F3	250	310	58	55
	F4	280	260	26	20
	F5	210	214	30	60
	F6	130	160	81	82
L.S.D 0.05		19.42	20.36	9.14	6.22

3.5. *Statistical Correlation Analysis*

Grain yield in wheat is generally, determined by some growth characters *viz*, plant height, No. of tillers/plant and yield component characteristics viz, spike length, No. of spikelets/ spike, No. of grains/spike and 1000 grain weight. Adequate knowledge of the relationship that exists between grain yield and yield-related characteristics is essential for the identification of selection criteria to be used for yield improvement. Correlations coefficients among studied plant growth and yield quality characteristics were estimated during 2018 /2019 and 2019 /2020 seasons and presented in Table (6). The results revealed that grain yield (ardab/fed.) was highly significant and positively correlated with plant height (*r*= .856** and .860**), No. of tillers/plant(*r*=.830** and .876**) , spike length(r=.740** and .712**), no. of spikelets / spike(*r*=.765** and .773**), no. of grains/spike(r=.758** and .767**) ,1000 grain weight(*r*=.739** and .648**) and straw yield (*r*=.9.88** and .999**) in the first and second seasons, respectively. The present findings are in agreement with that reported by (Fouad, 2018) who indicated that there was positive correlation between grain yield and each of number of spikes/plant and number of grains/spikes under different conditions. Waqar *et al.* (2010) declared that spike length, number of spikes per plant, number of spikelets per spike, number of grains per spike, number of tillers per m^2, 1000 grain weight were significantly and positively correlated with grain yield per plant.

Table 7. Correlation between plant height, No. of tillers/plant, spike length, No. of spikelets / spike, no. of grains/spike and 1000 grain weight in addition to grain and straw yields/fed. at 2018/ 2019 and 2019 /2020 seasons

Correlation r value	Plant height X1	No. of tillers/plant X2	Spike length X3	No. of spikelets / spike X4	No. of grains/spike X5	1000 grain weight X6	Grain yield Y	Straw yield X7
2018 /2019								
Plant height	1.00							
No.of tillers/plant	.857**	1.00						
Spike length	.498*	.487*	1.00					
No. of spikelets / spike	.641**	.542**	.819**	1.00				
No. of grains/spik	.631**	.532**	.821**	1.000**	1.00			
1000 grain weight	.560**	.498*	.836**	.907**	.907**	1.00		
Grain yield	.856**	.830**	.740**	.765**	.758**	.739**	1.00	
Straw yield	.847**	.818**	.784**	.757**	.751**	.757**	.988**	1.00
2019 /2020								
Plant height	1.00							
No.of tillers/plant	.779**	1.00						
Spike length	.405*	.584**	1.00					
No. of spikelets / spike	.532**	.677**	.949**	1.00				
No. of grains/spik	.582**	.676**	.829**	.805**	1.00			
1000 grain weight	.424*	.511*	.869**	.826**	.694**	1.00		
Grain yield	.860**	.876**	.712**	.773**	.767**	.648**	1.00	
Straw yield	.859**	.872**	.717**	.779**	.766**	.650**	.999**	1.00

**Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

4. Conclusion

Good fertilization management is critical for the high yielding, quality, and profitability of different wheat cultivars. In Egypt, increasing wheat yield production by improving grain yield/fed should reduce the vast gap between wheat production and consumption. A better understanding of red yeast's role in the soil rhizosphere fertilized with chemical nitrogen fertilizer holds a key to sustainable agricultural practices in the future while minimizing environmental risks. Based on the above results, it could be included that dual application of 75% of the recommended chemical N fertilizer with red yeast *Xanthophyllomyces dendrorhous* on Beni-swif (1, 5) durum wheat cultivars had maximized wheat productivity and net profit per fed. as well as decreased total costs and pollution due to the reduction of chemical fertilizers used. Therefore, it can be recommended to replace nitrogen chemical fertilization by red yeast biofertilizer with75% of the recommended chemical N to provide a high yield of Wheat while reducing the environmental pollution.

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