# The use of cyanobacteria as partial nitrogen source for maize (*Zea mays* L.) in presence of different mineral nitrogen rates

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**Abstract**: A field experiment was executed at EL-Nubaria Agricultural Research Station, Agricultural Research Centre (Latitude 30º 54′ 48.220″ N and Longitude 29º 51′ 50.834″ E), EL- Behera Governorate, Egypt, in two summer seasons of 2017 & 2018 to explore the influence of cyanobacteria (cyano) inoculation either as dry or liquid inoculum under the effect of different mineral nitrogen fertilizer rates on maize yield (variety single hybrid Giza 10) and yield components as well as, their impact on maize rhizosphere soil biological activity. Results revealed that in season 2018 early days to 50% tasseling ($Dtt_{50\%)}$ and days to 50% silking ($Dts_{50\%}$) had recorded significant differences due to the cyanobacteria treatment of dry + foliar spray in the same season. However, in the opposite cyanobacteria inoculation did not affect $Dtt_{50\%}$ and $Dts_{50\%}$ in 2017 season. On the other hand, the cyano-seed coating + dry cyano + foliar spray recorded the tallest plants and the highest values of ear heights. While, the shortest plant heights and the lowest ear heights values were due to using cyano-seed coating + foliar spray treatment. Also, the treatment of cyano-seed coating + dry cyano + foliar spray recorded the highest maize grain yield in both tested seasons. The treatment of cyano-seed coating + foliar spray gave the highest values for ear length (EL) and ear diameter (Ed). Cyanobacteria inoculation affected significantly the number of ears $row^{-1}$ (NE $Row^{-1}$) in 2017 and 2018 seasons. Tasseling and silking processes had positively affected by using mineral nitrogen fertilizer. Increasing nitrogen rates from $^{1}/_{2}$, $^{3}/_{4}$ up to full recommended rate gradually increased the values of plant and ear heights. Grain yield increases were correlated to the increase of nitrogen rate. Same trend, in grain yield was true with the maize yield component attributes. Moreover, using cyanobacteria along with different mineral nitrogen fertilizer rates increased the maize rhizosphere soil biological activity in as expressed by dehydrogenase and nitrogenase enzyme activities and carbon dioxide amount. Almost, cyanobacteria may save 25% from mineral nitrogen fertilizer necessary for maize production.

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## 1. Introduction

Cyanobacteria are gram negative oxygenic photosynthetic bacteria live commonly in either fresh, marine water and soil. They can fix the atmospheric nitrogen and to produce plant growth promoting substances. Thus, they are unique to contribute to the productivity in a variety of crops **(Mohan *et al*., 2015)**. Many works have been reported in using dried cyanobacteria to inoculate soils as to add to soil fertility and as biofertilizer for some cereal crops rather than rice **(Nayak and Prassana, 2007)** and **Lakshmi and Hussein, 2008)** and **Dola, 2010)**. Maize is amongst the most important cereal crops in the world agricultural economy due to its use as food for man and feed for animals **(Ali and Anjum, 2017).** In Egypt, grain yield production is not adequate to meet the ever increase in population and to cover the gap between production and local consumption. Therefore, any attempts are taken place to increase maize productivity through extensive use of agrochemical fertilizers especially nitrogen that is costly and create soil pollution and harm the environment **(Ghazal *et al*., 2013)**. Recently, a real challenge is to stop using high rates of agrochemicals, which adverse negatively human health and environment. Many trials have been tried to replace partially the harzard chemical fertilizers by biofertilizers to obtain yield of a high quality and quantity **(Getent and Dugasa, 2019).** The use of the nitrogen fixing cyanobacteria ensures saving entirely or partially the mineral nitrogen used in crop production. Recently, cyanobacteria attract the agronomic scientists to spend a great deal of interest in creating novel association between agrochemicals important plants, especially cereals such as maize and wheat and $N_2$-fixing microorganisms including cyanobacteria (**Subramaniyan *et al*., 2012, Abd EL-Kader, 2018) and Ghazal *et al*., 2018).** Biofertilizers can fix atmospheric nitrogen in the available form for plants **(Woldesenbet and Haileyesus, 2016)**. Positive response of maize to nitrogen fertilizer has been reported **(Ahmed *et al*., 2018)**

The aim of this study is to study the influence of cyanobacteria inoculation in presence of different mineral nitrogen fertilizer rates on maize yield and its components, as well as, on the biological activity of the soil rhizosphere maize plants in terms of dehydrogenase and nitrogenase enzyme activities and carbon dioxide amount.

## 2. Materials and Methods

A field experiment was executed at EL-Nubaria Agricultural Research Station, Agricultural Research Centre (ARC) (Latitude 30° 54′ 48.220″ N and Longitude 29° 51′ 50.834″ E), EL- Behera Governorate, Egypt, in two summer seasons of 2017 & 2018 to explore the influence of cyanobacteria inoculation either as dry or liquid inoculum under the effect of different mineral nitrogen fertilizer rates on maize yield (variety single hybrid Giza 10) and yield components, as well as, their impact on maize rhizosphere soil biological activity. Some physico – chemical analyses of the applied soil are present in (Table 1) according to **Jackson (1976)** and **Page *et al*. (1982)**. Maize seeds were kindly provided by Maize Res. Dept., Field Crops Res. Insti., (ARC), Giza, Egypt. Cyanobacteria inoculum was provided by Agric. Microbiol. Res. Dept., Soils, Water & Environ. Res. Inst., ARC, Giza, Egypt. Cyanobacteria inocula (cyano) were applied as dry inoculum form or liquid inoculum form. In both forms the inoculum contains a mixture of different cyanobacteria strains (*Nostoc carneum*, *Anabaena spherica, Calothrix marchica* and *Anabaena circinalis*). These nitrogen fixing cyanobacteria strains were kept and propagated using, the free nitrogen BG $11_0$ medium described by **Allen and Stanier (1968)**.

Table (1): Some physico-chemical characters of the applied soil

| **Chemical analyses** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **pH (1:2.5) Soil extract** | **EC $dSm^{-1}$ (Soil paste)** | **Soluble cations $meq\ L^{-1}$** | | | | **Soluble anions $meq\ L^{-1}$** | | | |
| | | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **$CO_3^{=}$** | **$HCO_3^{-}$** | **$Cl^{-}$** | **$SO_4^{=}$** |
| **8.60** | **0.97** | **2.20** | **1.70** | **3.70** | **2.10** | **00.00** | **3.20** | **3.40** | **3.10** |

| **Physical analyses** | | | | | |
|---|---|---|---|---|---|
| **Coarse sand** | **Fine sand** | **Silt** | **Clay** | **$CaCO_3$** | **Texture class** |
| **(%)** | | | | | **Sandy clay loam** |
| **15.93** | **30.15** | **24.98** | **26.85** | **20.10** | |

The liquid cyanobacteria inoculum was used either as foliar spray at a rate of 50 L $fed^{-1}$ or as seed coating for maize grains before planting. While, the dry cyanobacteria inoculum was applied at a rate of 3 kg $fed^{-1}$ at 10 days after planting as soil side dressing along the rows. Cyanobacteria treatments were 1) seed coating with liquid cyano plus sprayed with liquid cyano after 35 days from planting, 2) soil side dressing on the row (dry cyano) + sprayed with liquid cyano after 35 days from planting, 3) seed coating + Side dressing on the row (dry cyano) + sprayed after 35 days from planting, and 4) Control (without any addition); while the mineral nitrogen was added in rates of 150 kg $fed^{-1}$ (full recommended N, {FRN}) 75 kg $fed^{-1}$ ($^1/_2$ RN) and 112.5 kg $fed^{-1}$ ($^3/_4$ RN). Four replications was arranged in split-plot design, where cyano treatments represent the main plots and nitrogen rates represent the sub plots. Plot size was 5 rows, 6 m in length, 80 cm in width, and 20 cm between hills. One row was left between treatments to serve as blank. Nitrogen was applied as ammonium nitrate (33.5% N) added in eight equal split doses, the first was at germination, and the rest were applied weekly up to 65 days after planting. Phosphorus at a rate of 200 kg $P_2O_5$ $fed^{-1}$ as superphosphate (15% $P_2O_5$) and potassium at a rate of 50 kg $fed^{-1}$ as potassium sulphate (48% $K_2O$) were added at soil preparation. Soil samples were collected before planting for soil initial chemical and physical analyses. The parameters recorded for maize in both examined seasons were number of days from planting to 50% tasseling ($Dtt_{50\%}$), number of days from planting to 50% silking ($Dts_{50\%}$), plant height (Pht), ear heights (Eht) (cm), ear length (EL) (cm), ear diameter (Ed) (cm), number of ears $row^{-1}$ (NE $R^{-1}$), and grain yield (Gy) (t $fed^{-1}$) at 15.5% moisture. The maize rhizosphere soils were sampled at 65 days to figure the maize rhizosphere soil biological activity in terms of dehydrogenase activity (**Casida *et al*., 1964**), nitrogenase activity **(Hardy *et al*., 1973)** and $CO_2$ evolution amount (**Pramer and Schmidt, 1964**). The experiments were statistically designed and analyzed as described by **Gomez and Gomez (1984).**

## 3. Results and Discussion

### Effect of mineral nitrogen fertilizer

The response of maize growth, grain yield, and yield components to mineral nitrogen fertilizer was significant in both seasons, except for ear diameter in 2017 season (Table 2). In addition, nitrogen fertilizer had significantly affected $Dtt_{50\%}$ and $Dts_{50\%}$ in 2017 and 2018 season. Increasing nitrogen up to full N dose $fed^{-1}$ accelerated the time of tasseling and silking in 2017 and 2018 seasons. However, in 2017 season, there was no significant differences between $^{1}/_{2}$ and $^{3}/_{4}$ N $fed^{-1}$ for $Dtt_{50\%}$ and between $^{3}/_{4}$ N and full N $fed^{-1}$ for $Dts_{50\%}$. Whereas, significant differences among the three nitrogen rates for $Dtt_{50\%}$ and $Dts_{50\%}$ were detected in the second season. Generally, the earliest $Dtt_{50\%}$ and $Dts_{50\%}$ were associated with application of full N $fed^{-1}$ in the couple tested seasons.

Effect of nitrogen on plant height was significant in 2017 and 2018. Increasing nitrogen rates up to $^{3}/_{4}$ N $fed^{-1}$ was associated with the tallest plants in 2017. However, increasing N rates from $^{3}/_{4}$ to full N $fed^{-1}$ was not accompanied with a corresponding increase in plant height in the 2017 season. In the second season 2018, plant height increased when N increased up to the full N rate. On the other respect, the shortest plants were due to the application of $^{1}/_{2}$ N $fed^{-1}$ in both seasons. With respect to the ear height, nitrogen had significantly affected the ear height in 2017 and 2018 season. Increasing N up to $^{3}/_{4}$ N $fed^{-1}$ was associated with significant increase in ear height in 2017 season, while no significant difference was noticed between $^{3}/_{4}$ and full N rate due to their effect on ear height in season 2017. However, increasing full N rate attained the highest ear height in the second season 2018.

**Table (2): Effect of mineral nitrogen fertilizer on maize Dtt $_{50\%}$, Dts $_{50\%}$, Pht, Eht, EL (Cm), Ed (cm), NE $Row^{-1}$ and Gy in 2017 & 2018 Seasons**

| N rate $fed^{-1}$ | Dtt $_{50\%}$ | Dts $_{50\%}$ | Pht (cm) | Eht (cm) | EL (cm) | Ed (cm) | NE $Row^{-1}$ | Gy (t $fed^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **Season 2017** | | | | | | | | |
| **Full NR** | **58.90** | **60.70** | **270** | **138** | **18.80** | **4.51** | **45.00** | **3.64** |
| **$^{1}/_{2}$ NR** | **60.10** | **61.80** | **261** | **133** | **17.50** | **4.43** | **42.10** | **2.42** |
| **$^{3}/_{4}$ NR** | **59.70** | **61.00** | **272** | **140** | **18.40** | **4.47** | **43.10** | **2.81** |
| **$LSD_{0.05}$** | **0.50** | **0.40** | **4.00** | **4.00** | **0.40** | **NS** | **1.00** | **0.41** |
| **Season 2018** | | | | | | | | |
| **Full NR** | **61.80** | **63.50** | **304** | **166** | **18.60** | **4.36** | **45.80** | **3.98** |
| **$^{1}/_{2}$ NR** | **63.60** | **65.70** | **286** | **132** | **15.20** | **4.18** | **40.30** | **2.73** |
| **$^{3}/_{4}$ NR** | **62.70** | **64.60** | **304** | **146** | **16.80** | **4.28** | **43.90** | **3.65** |
| **$LSD_{0.05}$** | **0.03** | **040** | **5.00** | **5.00** | **0.30** | **0.07** | **0.70** | **0.39** |

Dtt $_{50\%}$ = days to 50% tasseling, Dts $_{50\%}$ = days to 50% silking, Pht = plant height, Eht = ear height, EL= ear length, Ed = ear diameter, NE $Row^{-1}$ = Number of ears per row and Gy= grain yield and NR = mineral nitrogen rate.

Furthermore, the lowest ear height of 133 and 132 cm were recorded using $^{1}/_{2}$ N rate in both tested seasons, respectively. Also, grain yield increased along with increasing the nitrogen rate from $^{1}/_{2}$ up full N rate in both tested seasons (Table 2). This increase in maize grain yield was more obvious with full N rate in 2017 season. But the difference between $^{3}/_{4}$ and full N treatments was not significant in 2018 season. This result detected that application of $^{1}/_{2}$ N rate led to the lowest grain yield (2.42 and 2.73 t $fed^{-1}$) in both tested seasons, respectively. Owing the yield components, ear length, ear diameter, and number of ears $row^{-1}$ had significantly influenced by N fertilizer rates in both seasons with exception for ear diameter in 2017 season (Table 2). Increasing N rate up to full N $fed^{-1}$ was accompanied by the tallest ears and the highest number of NE $Row^{-1}$ in both examined seasons. Moreover, the highest value for Ed achieved in the second season. However, in season 2017, no significant difference was noticed for the values of EL that achieved by $^{3}/_{4}$ and those achieved by full N rates. In this respect, **Gouda *et al.* (2009)** found that in maize cultivation, increasing nitrogen rates up to full N achieved the highest grain yield per unit area. **Dahmardeh (2011)** reported that increasing N up to 300 kg $fed^{-1}$ increased significantly all the tested parameters of maize yield. **Hokmalipour and Darbandi (2011)** postulated that in maize field experiment, increasing nitrogen dose up to 180 kg $ha^{-1}$ increased the harvest index, kernels yield, 1000 kernels weight, number of kernels per ear, and number of rows per ear. They also find out that increasing mineral nitrogen rates led to significant increases in 100 grain weight and grain yield. **Mukhtar *et al.* (2011)** showed that all tested nitrogen rate increased the plant height, grain number per ear, grains weight per ear and grains yield over control without nitrogen and these increases were more pronounced with high nitrogen rates. **Ghazal *et al.* (2013)** mentioned that raising mineral nitrogen rate from $^{3}/_{4}$ N to full N rate promoted grain yield of maize yield in comparison with control treatment. They consequently revealed that the variance in grain yield due to different applied nitrogen levels is connected to the variable size of photosynthetic surface and to the relative activity of total sink activity. **Mosaad (2016)** reported that nitrogen increase is positively correlated with photosynthetic contents in plant leaves and nitrogen content that enters enzymes responsible for photo synthesis processes in the chlorophyll molecule thus contributing in the accumulation of the dry matter and consequently increased the grain yield. In a field trial on maize crop, **Ali** and **Anjum (2017)** concluded that increasing nitrogen up to the recommended dose led to maximum yield traits and quality, i.e., plant height, stem diameter, leaf area plant$^{-1}$, chlorophyll content, dry matter yield, crude protein, crude fiber, and ash percentage. **Getnet** and **Dugasa (2019)** that maize positively responded to 120 kg N ha-1 the highest N rate and recorded significantly the highest grain yield, 1000 kernel weight, harvest index, leaf area index, plant height, ear lent and number of cobs plant$^{-1}$.

**Effect of cyanobacteria**

Table (3) revealed that maize responded significantly to cyanobacteria inoculation due to maize plant growth characters and grain yield in 2017 and 2018 seasons. No significant differences among cyanobacteria treatments for Dtt $_{50\%}$ and Dts $_{50\%}$ in 2017 season against nonsignificant impact in 2018 season. The behavior of both Dtt $_{50\%}$ and Dts $_{50\%}$ was related to the treatment of (dry cysno + foliar spray) in 2018 season. The treatment of coating with cyano + dry cyano + foliar spray assured the tallest maize plants and the highest ear heights in both examined seasons. While, the shortest plants and the lowest ear heights were due to using seed coating + dry cyano +foliar spray) in both 2017 and 2018 seasons. Grain yield significantly to cyanobacteria inoculation in the both seasons. The application of (seed coating + dry cyano + foliar spray) treatment gave the highest maize grain yield in the first and second seasons, respectively, against the lowest grain yield that resulted by the plants received no cynobacteria inoculation.

Cyanobacteria inoculation did not affect both of Ear length (EL) and ear diameter (Ed) in 2017 season, but in the contrarily, they significantly affected by cyano inoculation in 2018 season (Table 3). The highest values for EL and DL were given using the treatment of seed coating + foliar spray in the second season. Number of ears row$^{-1}$ (NE Row$^{-1}$) was significantly affected by cyanobacteria inoculation in 2017 and 2018and their highest values were related to the treatment of seed coating + dry cyano + foliar spray in both tested seasons.

**Table (3): Effect of cyanobacteria inoculation on maize Dtt $_{50\%}$, Dts $_{50\%}$, Pht, Eht, EL (Cm), Ed (cm), NE Row$^{-1}$and Gy in 2017 & 2018 Seasons**

| Cyanobacteria treatments | Dtt $_{50\%}$ | Dts $_{50\%}$ | Pht (cm) | Eht (cm) | EL (cm) | Ed (cm) | NE Row$^{-1}$ | Gy (t fed-$^{1}$) |
|---|---|---|---|---|---|---|---|---|
| Season 2017 | | | | | | | | |
| Seed coating + foliar spray | 59.80 | 61.3 | 260 | 134 | 18.0 | 3.57 | 42.60 | 3.58 |
| Dry + foliar spray | 59.40 | 61.2 | 264 | 132 | 18.3 | 3.55 | 44.10 | 3.20 |
| Coating + dry + foliar spray | 59.00 | 60.5 | 274 | 142 | 18.5 | 3.57 | 44.70 | 3.65 |
| Control | 60.00 | 61.6 | 271 | 136 | 18.1 | 3.60 | 42.20 | 2.96 |
| $LSD_{0.05}$ | NS | NS | 3.00 | 4.00 | NS | NS | 1.00 | 0.47 |
| Season 2018 | | | | | | | | |
| Seed coating + foliar spray | 63.40 | 65.20 | 273 | 141 | 17.10 | 3.52 | 43.20 | 3.41 |
| Dry + foliar spray | 62.30 | 64.10 | 278 | 146 | 16.90 | 3.42 | 43.50 | 3.35 |
| Coating + dry + foliar spray | 63.10 | 64.80 | 281 | 150 | 17.30 | 3.47 | 44.70 | 3.79 |
| Control | 62.70 | 64.60 | 276 | 150 | 16.10 | 3.25 | 41.80 | 3.25 |
| $LSD_{0.05}$ | 0.60 | 0.50 | 4.00 | 4.00 | 0.30 | 0.07 | 0.80 | 0.45 |

Dtt $_{50\%}$ = days to 50% tasseling, Dts $_{50\%}$ = days to 50% silking, Pht = plant height, Eht = ear height, EL= ear length, Ed = ear diameter, NE Row$^{-1}$ = Number of ears per row and Gy= grain yield.

**Effect cyanobacteria × nitrogen interaction**

Effect of cyanobacteria inoculation (cyano) × N rate interaction on $Dtt_{50\%}$ and $Dts_{50\%}$ was not significant in 2017, but this effect was positively significant in 2018 (Table 4). The use of full N rate along with dry cyano + foliar spray gave with the earliest $Dtt_{50\%}$ and $Dts_{50\%}$ in 2018 season. In contrast, application of $^{1}/_{2}$ N rate with seed coating + foliar spray was accompanied with the latest $Dtt_{50\%}$ and $Dts_{50\%}$ in 2018 season. Effect of cyanobacteria × N rate interaction on plant height (pht) was significant in 2017, but this effect was not significant in 2018 season. Application of $^{3}/_{4}$ N rate + seed coating + dry cyano + foliar spray gave the tallest plants (285 cm) in the first season, but with no significant difference with using full N rate without cyanobacteria inoculation (control) in the same season. In contrast, the shortest plants (260 cm) was in response of $^{1}/_{2}$ N rate (the lowest rate of N fertilizer) + seed coating + foliar spray treatment in 2017 season. No significant difference was detected between the tallest plants (285cm), which received ($^{3}/_{4}$ N rate + seed coating +

dry cyano + foliar spray) and the uninoculated that received the highest rate of N (full N rate). Effect of cyano × N interaction on grain yield was positively significant in both seasons (Table 4). There was no significant difference between $^3/_4$ N and full N rate (without inoculation) for grain yield in both tested seasons. The highest grain yield (4.63 and 4.18 t fed$^{-1}$) resulted from full N rate along with the treatment of seed coating + dry cyano + foliar spray in both 2017 and 2018 seasons, respectively. However, no significant difference was detected between the rate of $^3/_4$ N and full N rate + seed coating and the treatment of full N rate + dry cyano + foliar spray and between the rate of $^1/_2$ and $^3/_4$ N rate combined with dry cyano + foliar spray in 2017 season. In contrast, significant differences amongst the three nitrogen levels were detected with seed coating + dry cyano + foliar spray in 2017 season. While, in the second season, there were no significant differences between $^3/_4$ N rate and full N rate for all treatments of cyanobacteria.

**Table (4): Impact of cyanobacteria-nitrogen interaction on maize Dtt $_{50\%}$, Dts $_{50\%}$, Pht and Gy in 2017 and 2018 seasons**

| Cyanobacteria treatments | N rate fed [1] | **Dtt $_{50\%}$** | **Dts $_{50\%}$** | **Pht (cm)** | Gy (t fed-$^1$) |
|---|---|---|---|---|---|
| **Season 2017** | | | | | |
| **Seed coating + foliar spray** | **Full NR** | **59.30** | **61.00** | **280** | **4.31** |
| | **$^1/_2$ NR** | **58.00** | **62.00** | **270** | **2.80** |
| | **$^3/_4$ NR** | **59.00** | **62.00** | **285** | **3.62** |
| **Dry + foliar spray** | **Full NR** | **59.30** | **62.00** | **281** | **3.82** |
| | **$^1/_2$ NR** | **61.02** | **61.90** | **268** | **2.74** |
| | **$^3/_4$ NR** | **60.50** | **62.00** | **383** | **3.03** |
| **Coating + dry + foliar spray** | **Full NR** | **59.30** | **61.00** | **284** | **4.63** |
| | **$^1/_2$ NR** | **61.00** | **62.10** | **260** | **3.81** |
| | **$^3/_4$ NR** | **60.00** | **62.50** | **289** | **3.74** |
| **Control** | **Full NR** | **58.90** | **60.70** | **279** | **3.64** |
| | **$^1/_2$ NR** | **60.10** | **61.80** | **261** | **2.42** |
| | **$^3/_4$ NR** | **59.70** | **61.00** | **272** | **3.81** |
| **$LSD_{0.05}$** | | **NS** | **NS** | **8.60** | **1.05** |
| **Season 2018** | | | | | |
| **Seed coating + foliar spray** | **FNR** | **62.00** | **64.80** | **300** | **4.15** |
| | **$^1/_2$ NR** | **65.80** | **65.80** | **243** | **2.53** |
| | **$^3/_4$ NR** | **64.50** | **65.80** | **285** | **3.59** |
| **Dry + foliar spray** | **FNR** | **65.30** | **64.00** | **308** | **3.86** |
| | **$^1/_2$ NR** | **64.50** | **66.30** | **254** | **2.79** |
| | **$^3/_4$ NR** | **66.00** | **65.00** | **285** | **3.40** |
| **Coating + dry + foliar spray** | **FNR** | **63.50** | **65.30** | **316** | **4.18** |
| | **$^1/_2$ NR** | **64.50** | **66.00** | **251** | **3.02** |
| | **$^3/_4$ NR** | **69.80** | **66.00** | **289** | **4.17** |
| **Control** | **FNR** | **61.80** | **63.50** | **304** | **3.98** |
| | **$^1/_2$ NR** | **63.60** | **65.70** | **286** | **2.73** |
| | **$^3/_4$ NR** | **62.70** | **64.60** | **304** | **2.81** |
| **$LSD_{0.05}$** | | **0.60** | **0.90** | **NS** | **1.87** |

Dtt $_{50\%}$ = days to 50% tasseling, Dts $_{50\%}$ = days to 50% silking, Pht = plant height and Gy= grain yield.

**Effect of mineral nitrogen and cyanobacteria inoculation on maize rhizosphere soil biological activity**

The current study, inoculation of maize plants with cyanobacteria combined with different mineral nitrogen fertilizer rates (full recommended, $^1/_2$ and $^3/_4$ rates) encouraged maize rhizosphere soil biological activity for both tested seasons in terms dehydrogenase activity, nitrogenase activity and carbon dioxide evolution compared to the control treatment without cyanobacteria inoculation (Table 5). The treatment of $^3/_4$ NR + cyano-seed coating + dry cyano + foliar spray gave the highest values of 830.86 mg TPF g dry rhizosphere soil$^{-1}$ day$^{-1}$ (DHA), 460.61 mmole $C_2H_2$ g dry rhizosphere soil$^{-1}$ day$^{-1}$ ($N_2$-ase) and 1015.25 mg $CO_2$ 100 g dry rhizosphere soil$^{-1}$ day$^{-1}$ ($CO_2$ evolution) in the first season and 740.95 mg TPF g dry rhizosphere soil$^{-1}$ day$^{-1}$ (DHA), 395.45 mmole $C_2H_2$ g dry rhizosphere soil$^{-1}$ day$^{-1}$ ($N_2$-ase) and 945.25 mg $CO_2$ 100 g dry rhizosphere soil$^{-1}$ day$^{-1}$ ($CO_2$ evolution). However, the least values for these biological parameters were recorded by the mineral nitrogen treatments without cyanobacteria application. In this aspect, **Zulpa *et al*. (2008) and Caire *et al*. (2000)** found the inoculation with cyanobacteria increased that the biomass and extracellular products, the soil microbial community and its nutrients availability. They added that soil inoculation with *Nostoc muscorum* and *Tolypothrix tenuis* increased the soil oxidized carbon. These increases led to increase the soil biological activity. The Production of bioactive substances by cyanobacteria accelerates the soil enzymatic activity. Besides, exopolysaccharide secreted by cyanobacteria are a source of organic carbon for the soil microflora increasing microbial activity **(Storni de Cano *et al*., 2002)**. They also added that cyanobacteria inoculation to maize field enhanced significantly any of total count bacteria, cyanobacteria count, $CO_2$ evolution, dehydrogenase and nitrogenase activities compared to the control treatment received no inoculation. They explained that biofertilization with cyanobacteria led to increase microorganisms' community and in turn enhanced soil biological activity in soil through increasing the organic matter and microbial activity. **Ghazal *et al.* (2013)** noted that inoculation with cyanobacteria to maize plants accelerated the maize rhizosphere soil biological activity in terms of carbon dioxide evolution, dehydrogenase activity and nitrogenase activity. Also, in wheat cultivation, **EL-Beltagy *et al.* (2016)** reported that in wheat cultivation, the treatment of 75% recommended N dose + cyanobacteria inoculation gave the highest soil biological activity as dehydrogenase activity, nitrogenase activity and $CO_2$ evolution compared to those recorded by the treatments 50% recommended N dose + cyanobacteria and any nitrogen applied dose alone.

**Table (5): Maize rhizosphere soil dehydrogenase activity (DHA), nitrogenase activity ($N_2$-ase) and $CO_2$ evolution as affected by mineral nitrogen fertilizer rats (NR) and cyanobacteria inoculation (cyano)**

| N rate fed$^{-1}$ | Cyano treatments | DHA (mg TPF* g dR** soil-1 day$^{-1}$) | $N_2$-ase (mmole $C_2H_2$ g dR soil $^{-1}$day$^{-1}$) | $CO_2$ evolution (mg $CO_2$ 100 g dR soil $^{-1}$day$^{-1}$) |
|---|---|---|---|---|
| **Season 2017** | | | | |
| Full NR | Seed coating + foliar spray | 345.42 | 50.12 | 318.43 |
| | Dry + foliar spray | 520.74 | 81.36 | 730.45 |
| | Seed coating +dry + foliar spray | 615.43 | 230.74 | 913.40 |
| 1/2 NR | Seed coating + foliar spray | 325.23 | 42.56 | 268.15 |
| | Dry + foliar spray | 420.08 | 65.78 | 660.25 |
| | Seed coating +dry + foliar spray | 510.75 | 170.16 | 835.33 |
| 3/4 NR | Seed coating + foliar spray | 530.55 | 82.18 | 510.67 |
| | Dry + foliar spray | 690.28 | 190.85 | 835.53 |
| | Seed coating +dry + foliar spray | 830.86 | 460.61 | 1015.25 |
| Control | Full NR | 91.72 | 41.62 | 145.06 |
| | $^1/_2$ NR | 75.10 | 30.45 | 130.12 |
| | $^3/_4$ NR | 110.12 | 52.15 | 108.58 |
| **Season 2018** | | | | |
| FNR | Seed coating + foliar spray | 281.45 | 45.25 | 288.43 |
| | Dry + foliar spray | 510.54 | 72.34 | 630.45 |
| | Seed coating +dry + foliar spray | 595.60 | 2150.85 | 724.40 |
| 1/2 NR | Seed coating + foliar spray | 345.23 | 39.86 | 218.15 |
| | Dry + foliar spray | 400.12 | 55.95 | 460.25 |
| | Seed coating +dry + foliar spray | 480.75 | 162.58 | 635.33 |
| 3/4 NR | Seed coating + foliar spray | 485.55 | 70.18 | 310.67 |
| | Dry + foliar spray | 690.28 | 165.85 | 855.29 |
| | Seed coating +dry + foliar spray | 740.95 | 395.45 | 945.53 |
| Control | Full NR | 85.56 | 34.32 | 145.06 |
| | $^1/_2$ NR | 70.19 | 28.55 | 98.12 |
| | $^3/_4$ NR | 99.64 | 49.15 | 118.58 |

***TPF = Tri - phenyl formazan ** dR = dry rhizosphere.**

In conclusion, results from the present study indicate that the application of cyanobacteria and nitrogen fertilizer rate can positively affect the maize yield and its components, especially for the treatment received $^{3}/_{4}$ N (112.5 kg N fed$^{-1}$) + cyano seed coating + dry cyano + foliar spray, which gave maize yield was not significantly differed from that given by full N dose alone (150 kg N fed$^{-1}$). Generally, cyanobacteria inoculation to maize in combination with $^{3}/_{4}$ mineral nitrogen fertilizer can minimize the required chemical fertilizers and subsequently hinder environmental pollution and become eco-friendly.

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