# EFFECT OF DIFFERENT LEVELS OF FERTILIZERS IN COMBINATION WITH BIOFERTILIZERS ON NUTRIENT CONTENTAND UPTAKE OF *KHARIF* MAIZE

## *ABSTRACT*

A field experiment entitled **"Effect of different levels of fertilizers in combination with biofertilizers on nutrient content and uptake of *kharif* maize"** was conducted at Agriculture College Farm, Bapatla, during both *kharif* 2020 and 2021. The experiment was laid out in randomized block design (RBD) with seven treatments and replicated thrice. The treatments consisted of $T_1$- Control; $T_2$- 100% RDF; $T_3$- 125% RDF; $T_4$ – 100% RDF + VAM; $T_5$- 100% RDF +VAM + *Azospirillum* + PSB; $T_6$- 75 % RDF + VAM; $T_7$- 75 % RDF + VAM + *Azospirillum* + PSB. During *kharif* in two years of study significantly higher nitrogen content and uptake was recorded with 125 % RDF ($T_3$) it was on par with 100% RDF + VAM + *Azospirillum* + PSB ($T_5$) and 100% RDF + VAM ($T_4$). The aim of this study was to see the effect of different levels of fertilizers along with biofertilizers on nutrient content and uptake by maize crop. Higher phosphorus, potassium and sulphur (non-significant) content and uptake were recorded in the treatment $T_5$ that received 100% RDF +VAM + *Azospirillum* + PSB and it was on par with treatment which received 75 % RDF + VAM + *Azospirillum* + PSB ($T_7$), 125 % RDF ($T_3$) and 100% RDF + VAM ($T_4$) at knee high, tasseling and harvest stage of maize. The results revealed that application of biofertilizers along with inorganic fertilizers significant increased plant nutrient content and uptake of maize crop.

***Key words***: Biofertilizers, Fertilizer levels, Plant nutrient content and Uptake.

## 1.INTRODUCTION

Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 % (782 m t) in the global grain production. In India, maize is the third most important food crops after rice and wheat. Maize in India, contributes nearly 9 % in the national food basket. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. Maize is cultivated both in temperate and tropical regions of the world. The full yield potential of maize crop can be exploited through adoption of hybrids with better nitrogen management practices.

The combined application of inorganic fertilizers and biofertilizers significantly increased the N, P, K and micro nutrient content and uptake in *kharif* maize, in straw and in grain. This might be due to combined application of inorganic fertilizers and biofertilizers enhance root growth and cell multiplication leading to more absorption of nutrients from deeper layers of soil ultimately resulting in increased N, P, K and micro nutrient content and uptake. The application of biofertilizers (PSB, *Azospirillum* and VAM) plays a vital role in solubilization of various inorganic and organic phosphates added to the soil. It may also release soluble phosphorus into the soil through the decomposition of phosphorus from organic compounds.

Besides its role in metabolic process and energy transformations, P considerably influences root proliferation which are seat of biological nitrogen fixation and helps plants to draw nutrients from lower layers and consequently thrive under moisture stress conditions (Singh *et al*. 2003). A large portion of applied inorganic fertilizers (N and P) may be fixed to iron and alluminium oxides and then not available to plant uptake (Kumar *et al*. 2015). The very high inorganic fertilizer prices also demand the need for recycling and exploitation of fixed phosphorus to improve crop production. Therefore, the current trend is to explore the possibility of supplementing fertilizers with organic manures and biofertilizers.

## 2.MATERIAL AND METHODS

### 2.1 Site Description

The field experiment was carried out during both *kharif* seasons of 2020-2021 at Agricultural College Farm, Bapatla. Geographically located at an altitude of 5.49 m above mean sea level, $15^{o}54'$ North latitude, $80^{0}30'$ East longitude and about 8 km away from Bay of Bengal. It is located in Krishna agro-climatic zone of Andhra Pradesh. The experimental soil was clay loam in texture, slightly alkaline in reaction (pH 7.56), non- saline (0.64 dS $m^{-1}$), medium in organic carbon (5.4 g $kg^{-1}$), medium in available nitrogen (283 kg $ha^{-1}$), medium in available phosphorus (42.5 kg $ha^{-1}$), high in potassium (426 kg $ha^{-1}$) and medium in sulphur (14.3 mg $kg^{-1}$) and sufficient in all micronutrients (6.81, 5.43, 1.37 and 0.58) (Fe, Mn, Cu and Zn).

### 2.2 Experimental design and treatments

The experiment was laid out in randomized block design (RBD) with seven treatments and replicated thrice. The experimental treatment details are as following $T_1$- Control; $T_2$- 100% RDF; $T_3$- 125% RDF; $T_4$ – 100% RDF + VAM; $T_5$- 100% RDF +VAM + *Azospirillum* + PSB; $T_6$-

75 % RDF + VAM; $T_7$- 75 % RDF + VAM + *Azospirillum* + PSB. RDF for maize 200:60:50 kg $ha^{-1}$ N, $P_2O_5$ and $K_2O$ through applied Urea, Single super phosphate and Muriate of potash and biofertilizers like VAM -12.5 kg $ha^{-1}$, *Azospirillum* -5 kg $ha^{-1}$ and PSB -5 kg $ha^{-1}$ through applied vermicompost. The popular hybrid of maize Pioneer 3396 was chosen for the study.

**2.3 Collection and Preparation of plant Samples:** Plant samples of maize was collected from five randomly selected plants at knee high, tasseling and harvest stage. The samples were first dried in shade and then in hot air oven at 65 $^oC$. The plant samples were ground in willey mill and stored in labeled brown paper bags for analysis. The grain samples were also processed and stored in similar fashion.

**2.4 Methods used for plant analysis:**

Nitrogen content in plant samples was determined by micro Kjeldahl method (Piper, 1966). Di-acid extract was prepared as per the method outlined by Jackson (1973). It was carried out using a 9:4 mixture of $HNO_3$: $HClO_4$. The pre digestion of sample was done by using 10ml of $HNO_3$ $g^{-1}$ sample. This di-acid extract was used to determine P, K and sulphur content in the plant and grain samples. Phosphorus in the diacid extract of plant samples was estimated by vanado molybdo phosphoric yellow colour method using spectrophotometer at 420 nm wave length. Potassium in the diacid extract of plant samples was determined using flame photometer as per the method described by Jackson (1973). Sulphur in the di-acid extract of plant samples was estimated by turbidity metric method using spectrophotometer at 420 nm (Chesnin and Yien, 1950). The data on various parameters was statistically analysed by using Fisher's method of analysis of variance as suggested by (Panse and Sukhatme, 1978) for the randomized block design adopted in this study. Statistical significance was tested by applying F-test at 0.05 level of probability. Critical differences at 0.05 levels were worked out for the effects, which were significant



**2.5 Nutrient Uptake by Maize Crop**

From the chemical analytical data, uptake of the macro nutrients at knee high, tasseling and harvest of the maize crop was calculated and expressed by using the formulae.

Nutrient content (%) x dry weight in kg $ha^{-1}$

Macronutrient uptake (kg ha $^{-1}$) = --------------------------------------------------------
100

# 3. RESULTS AND DISCUSSION

## 3.1. Nutrient Content

### 3.1.1 Nitrogen Content

The results revealed that significantly higher nitrogen content was recorded in the treatment $T_5$ *i.e.*, 100% RDF + VAM + *Azospirillum* and PSB (2.45,2.34,0.75,1.73 % in 2020 and 2.57,2.43,0.81,1.85 % in 2021) and it was on par with the treatments $T_7$ ,$T_3$ and $T_4$ at knee high, tasseling and harvest (straw + grain) stages of maize crop during *kharif*, 2020 and 2021, respectively (Table-1). The lowest nitrogen content was recorded with the treatment $T_1$ *i.e.*, control (1.65,1.49,0.51,1.27 % in 2020 and 1.76,1.57,0.52,1.32 % in 2021). Significantly higher N content was observed in the treatments having combined application of biofertilizers with inorganic fertilizers as compared to control treatment. The higher N content in treatments which are supplied with *Azospirillum* might be because of an increase in NUE (Nitrogen Use Efficiency) (Zeffa *et al*., 2019). Also the increase in efficiency of *Azospirillum* with increase in N rates up to 200 kg ha$^{-1}$ was also reported by Galindo *et al*. (2019). This might be due to the fact that inorganic component provided nutrients during early stages of the crop growth while the organic component provided nutrients at the later stage of the crop development as it takes some time for the mineralization. Similar results were also reported by Prabhavathi *et al*. (2021).

### 3.1.2 Phosphorus Content

Significantly higher phosphorus content was recorded in the treatment received 100% RDF+ VAM + *Azospirillum* and PSB ($T_5$) (0.38, 0.32, 0.13, 0.30% in 2020 and 0.58, 0.47, 0.19, 0.37 % in 2021) and it was on par with the treatments $T_7$, $T_3$ and $T_4$ at knee high, tasseling and harvest (straw + grain) stages of maize crop growth during 2020 and 2021, respectively. The lowest phosphorus content was recorded with the treatment $T_1$ *i.e.*, control (0.18, 0.15, 0.04, 0.15 % in 2020 and 0.32, 0.19, 0.09, 0.17 % in 2021) (Table-2). The P content in maize straw decreased with the growth stage from knee high to harvest stage in straw and the P content in grain was higher when compared to straw. This could be attributed to the translocation of large proportions of phosphorus from other parts of the plant to the kernel as the kernel developed (Hussaini *et al*., 2008). Application of inorganics and the addition of biofertilizer (PSB) might have increased P availability in the soil due to the solubilizing effect which must have increased the absorption by plant roots and thereby the uptake by the plant have reflected in the increase in P concentration in the plant. The combined application of inorganics and biofertilizers (*Azospirullum* and PSB) enhanced favourable nutritional environment to the plant rhizosphere that might have increased the phosphorous content. These findings corroborate with the results obtained by Davari *et al*. (2012).

### 3.1.3 Potassium Content

The results revealed that significantly higher potassium content was recorded in $T_5$ which received 100% RDF + VAM + *Azospirillum* and PSB (2.67, 2.44, 2.29, 0.35 % in 2020 and 2.78, 2.62, 2.37, 0.46 % in 2021) and it was on par with the treatments $T_7$, $T_3$ and $T_4$ at knee high, tasseling and harvest (straw + grain) stages of maize crop growth during 2020 and 2021, respectively (Table-3). The lowest potassium content was recorded with the treatment $T_1$ *i.e*., control (1.95, 1.78, 1.62, 0.18 % in 2020 and 2.06, 1.88, 1.72, 0.20 % in 2021). Irrespective of the year of the study, K content in maize decreased from knee high to harvest. The maximum K content was recorded at knee high in all treatments. The K content in grain was recorded low in all treatments when compared to maize straw at all growth stages of maize. These results are in close conformity with the findings of Islam *et al.* (2010). The higher build up of available K in the soil treated with application of biofertilizers and inorganics might have influenced the K absorption by plant. Also, the additional effect of improvement in plant nutrition status might be due to organic component and also due to inorganic dose which in combination gave better result in integrated treatments (Kumar *et al*., 2020).

### 3.1.4 Sulphur Content

Sulphur content in maize presented in table-4 revealed that there was no significant difference at all the stages of crop growth during both the years of study. Among various treatments that received 100% RDF + VAM + *Azospirillum* and PSB ($T_5$) was recorded numerically higher sulphur content (0.27, 0.24, 0.13, 0.35 mg kg$^{-1}$ in 2020 and 0.29, 0.26, 0.15, 0.37 mg kg$^{-1}$ in 2021) at knee high, tasseling and harvest (stover and grain) stages of maize crop, respectively. The lowest sulphur content was recorded with the treatment $T_1$ *i.e*., control (0.18, 0.16, 0.06, 0.26 mg kg$^{-1}$ in 2020 and 0.20, 0.17, 0.07, 0.27 mg kg$^{-1}$ in 2021). This might be due to application biofertilizer and inorganics slightly increased but non significantly influenced sulphur content at all the stages of crop growth. Irrespective of the year of the study, the S content in maize straw decreased with the growth stage from knee high to harvest stage in straw and the S content in grain was higher when compared to straw. Data indicated a considerable increase in available sulphur in inorganics and biofertilizer treatments at all the growth stages.

## 3.2 Nutrient Uptake

### 3.2.1 Nitrogen Uptake

Significantly higher nitrogen uptake was recorded in $T_5$ which received 100% RDF + VAM + *Azospirillum* and PSB (41.65, 166.49, 63.14, 101.99 kg $ha^{-1}$ in 2020 and 46.17, 174.69, 69.79, 120.55 kg $ha^{-1}$ in 2021) and it was on par with the treatments $T_7$, $T_3$ and $T_4$ at knee high, tasseling and harvest (straw + grain) stages of maize crop growth during 2020 and 2021, respectively (Table-5). The lowest nitrogen uptake was recorded with the treatment $T_1$ *i.e*., control (16.52, 67.62, 27.11, 49.19 kg $ha^{-1}$ in 2020 and 18.45, 72.78, 28.12, 53.34 kg $ha^{-1}$ in 2021). The data revealed that uptake of nitrogen was more at harvest (straw + grain) compared to tasseling and kneehigh stages. Higher biomass production is the most prominent reason for the higher uptake in the integrated nutrient management practices. The increase in nitrogen uptake could be ascribed to slow and continuous supply of the nutrients, coupled with reduced nitrogen losses via denitrification or leaching, which might have improved the synchrony between plant nitrogen demand and supply from the soil (Tilahun *et al*., 2013). These biofertilizers increased the uptake of nutrients through mineralization but also reduce the losses of N through leaching and volatilization (Meena *et al*., 2013). The *Azospirillum* has the ability to produce biologically active substances and it produce a significant amount of available nitrogen through biological nitrogen fixation, improving photosynthesis and promoting root growth which in turn enhances nutrient uptake (Chaudhary *et al*., 2020).

### 3.2.2 Phosphorus Uptake

Significantly higher phosphorus uptake was recorded in $T_5$ which received 100% RDF + VAM + *Azospirillum* and PSB (5.04, 23.01, 10.06, 18.33 kg $ha^{-1}$ in 2020 and 10.54, 34.40, 15.73, 24.32 kg $ha^{-1}$ in 2021) and it was on par with the treatments $T_7$, $T_3$ and $T_4$ at knee high, tasseling and harvest (straw + grain) stages of maize crop growth during 2020 and 2021, respectively (Table-6). The lowest phosphorus uptake was recorded with the treatment $T_1$ *i.e*., control (1.79, 6.74, 2.11, 5.81 kg $ha^{-1}$ in 2020 and 3.34, 8.73, 5.03, 6.86 kg $ha^{-1}$ in 2021). The increased P uptake could be due to higher drymatter accumulation at different stages of crop growth as uptake being the product of nutrient content and drymatter accumulation. The $CO_2$ produced during mineralization of organic sources play a vital role in solubilization of native P (Nirukumari *et al.*, 2013). The higher P uptake could be attributed to the increased P availability and increased root growth of the crop. The pH of the soil also indicated a positive change *i.e.,* a shift towards neutrality. This positive change enhanced the solubility of different nutrients especially phosphorus in the soil which increased the uptake of phosphorus. These results are in conformity with the findings of Jaffarbasha *et al.* (2017).

### 3.2.3 Potassium Uptake

Irrespective of the growth stages of maize (Table-7), significantly the highest K uptake was recorded in the treatment $T_5$ *i.e.*, 100% RDF + VAM + *Azospirillum* and PSB (45.47, 174.22, 194.07, 21.23 kg ha$^{-1}$ in 2020 and 50.22, 188.26, 205.42, 29.88 kg ha$^{-1}$ in 2021) and it was on par with the treatments $T_7$, $T_3$ and $T_4$ at knee high, tasseling and harvest (straw + grain) stages of maize crop growth during 2020 and 2021, respectively. The lowest potassium uptake was recorded with the treatment $T_1$ *i.e.*, control (19.40, 79.70, 86.11, 6.97 kg ha$^{-1}$ in 2020 and 21.50, 86.42, 93.01, 8.08 kg ha$^{-1}$ in 2021). The potassium uptake by the crop was increased with increase in level of fertilizers which might be due to the enhanced number of small root hairs which in turn facilitated the absorbing ability per unit dry weight (Sunitha and Reddy, 2012). The increase in uptake of potassium in inorganic, organic and biofertilizer treated plots might be due to release of K from manures during decomposition and solution with $K^+$ ions. The increase in uptake with growth may be ascribed to split application of potassic fertilizers and the role of inorganic, organics and biofertilizers in increasing the use efficiency of applied fertilizers. The results are coinciding with Mahavishnan *et al*. (2004) and Hammad *et al*. (2011). Increased K uptake might be due to the synergistic effect between P and K and also phosphorus biofertilizers which makes solubilizing K from K bearing minerals through organic acids released that could have increased K content in grain. The present findings are in accordance with findings of Sharma *et al*. (2012).

### 3.2.4 Sulphur Uptake

The results revealed that at all the three stages *viz*., at knee high, tasseling and harvest (straw and grain) stages of maize, the treatment $T_5$ *i.e*., 100% RDF + VAM + *Azospirillum* and PSB (4.57, 16.53, 10.33, 21.86 g ha$^{-1}$ in 2020 and 4.60, 17.30, 12.36, 23.98 g ha$^{-1}$ in 2021) significantly the highest S uptake was recorded and it was on par with the treatments $T_7$, $T_3$ and $T_4$ during 2020 and 2021, respectively (Table-8). The lowest sulphur uptake was recorded with the treatment $T_1$ *i.e*., control (1.61, 5.78, 3.19, 8.15 g ha$^{-1}$ in 2020 and 1.81, 6.55, 3.80, 8.99 g ha$^{-1}$ in 2021). Yadav *et al*. (2013) stated that the highest sulphur uptake with organic manures, inorganic and biofertilizers application might be due to solubilization of native nutrients, chelation of complex intermediate organic molecules produced during decomposition of added organic manures, their mobilization and accumulation of different nutrients in different plant parts. The results are corroborated with the findings of Meghadubey *et al*. (2015).

## 4.Conclusion

The combined application of inorganic and biofertilizers significantly increased nutrient content and uptake at different growth stages of maize crop. The split application of inorganic fertilizers increased plant nutrient content and uptake of maize. The additional effect of improvement in plant nutrition status might be due to biofertilizers and inorganic dose which in combination gave better result in integrated treatments. The increased nutrient uptake could be due to higher drymatter accumulation at different stages of crop growth as uptake being the product of nutrient content and drymatter accumulation.

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**Table 1. Effect of different levels of fertilizers in combination with biofertilizers on nitrogen content (%) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Knee high | Tasseling | Harvest | | Knee high | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 1.65 | 1.49 | 0.51 | 1.27 | 1.76 | 1.57 | 0.52 | 1.32 |
| $T_2$: 100% RDF | 2.07 | 1.98 | 0.62 | 1.51 | 2.18 | 2.05 | 0.66 | 1.59 |
| $T_3$: 125% RDF | 2.33 | 2.21 | 0.69 | 1.65 | 2.44 | 2.30 | 0.75 | 1.73 |
| $T_4$: 100% RDF + VAM | 2.29 | 2.18 | 0.67 | 1.62 | 2.41 | 2.25 | 0.74 | 1.71 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 2.45 | 2.34 | 0.75 | 1.73 | 2.57 | 2.43 | 0.81 | 1.85 |
| $T_6$: 75% RDF + VAM | 1.99 | 1.86 | 0.60 | 1.49 | 2.08 | 1.96 | 0.63 | 1.56 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 2.37 | 2.23 | 0.71 | 1.69 | 2.50 | 2.32 | 0.77 | 1.80 |
| **SEm (±)** | 0.11 | 0.11 | 0.03 | 0.07 | 0.10 | 0.12 | 0.03 | 0.07 |
| **CD (P=0.05)** | 0.33 | 0.34 | 0.08 | 0.20 | 0.31 | 0.35 | 0.09 | 0.21 |
| **CV (%)** | 8.72 | 9.41 | 7.74 | 7.52 | 7.76 | 9.66 | 7.56 | 7.09 |

**Table 2. Effect of different levels of fertilizers in combination with biofertilizers on phosphorus content (%) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Knee high | Tasseling | Harvest | | Knee high | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 0.18 | 0.15 | 0.04 | 0.15 | 0.32 | 0.19 | 0.09 | 0.17 |
| $T_2$: 100% RDF | 0.27 | 0.24 | 0.09 | 0.21 | 0.42 | 0.30 | 0.14 | 0.27 |
| $T_3$: 125% RDF | 0.34 | 0.28 | 0.11 | 0.26 | 0.54 | 0.39 | 0.17 | 0.33 |
| $T_4$: 100% RDF + VAM | 0.33 | 0.26 | 0.11 | 0.25 | 0.51 | 0.38 | 0.16 | 0.32 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 0.38 | 0.32 | 0.13 | 0.30 | 0.58 | 0.47 | 0.19 | 0.37 |
| $T_6$: 75% RDF + VAM | 0.26 | 0.22 | 0.08 | 0.20 | 0.40 | 0.29 | 0.13 | 0.26 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 0.36 | 0.30 | 0.12 | 0.28 | 0.55 | 0.42 | 0.18 | 0.34 |
| **SEm (±)** | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 | 0.01 | 0.03 |
| **CD (P=0.05)** | 0.06 | 0.05 | 0.02 | 0.04 | 0.07 | 0.09 | 0.02 | 0.08 |
| **CV (%)** | 10.06 | 10.84 | 12.06 | 11.71 | 8.55 | 13.48 | 8.79 | 14.44 |

**Table 3. Effect of different levels of fertilizers in combination with biofertilizers on potassium content (%) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Kneehigh | Tasseling | Harvest | | Kneehigh | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 1.95 | 1.78 | 1.62 | 0.18 | 2.06 | 1.88 | 1.72 | 0.20 |
| $T_2$: 100% RDF | 2.34 | 2.15 | 1.98 | 0.26 | 2.45 | 2.29 | 2.06 | 0.33 |
| $T_3$: 125% RDF | 2.60 | 2.39 | 2.23 | 0.30 | 2.71 | 2.50 | 2.29 | 0.38 |
| $T_4$: 100% RDF + VAM | 2.58 | 2.36 | 2.20 | 0.29 | 2.69 | 2.50 | 2.27 | 0.37 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 2.67 | 2.44 | 2.29 | 0.35 | 2.78 | 2.62 | 2.37 | 0.46 |
| $T_6$: 75% RDF + VAM | 2.31 | 2.12 | 1.95 | 0.25 | 2.42 | 2.23 | 2.03 | 0.31 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 2.63 | 2.41 | 2.26 | 0.33 | 2.77 | 2.53 | 2.34 | 0.41 |
| **SEm (±)** | 0.10 | 0.09 | 0.09 | 0.02 | 0.10 | 0.09 | 0.09 | 0.03 |
| **CD (P=0.05)** | 0.31 | 0.28 | 0.27 | 0.06 | 0.31 | 0.27 | 0.26 | 0.08 |
| **CV (%)** | 7.12 | 6.89 | 7.11 | 10.96 | 6.79 | 6.41 | 6.77 | 12.84 |

**Table 4. Effect of different levels of fertilizers in combination with biofertilizers on sulphur content (mg $kg^{-1}$) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Knee high | Tasseling | Harvest | | Knee high | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 0.18 | 0.16 | 0.06 | 0.26 | 0.20 | 0.17 | 0.07 | 0.27 |
| $T_2$: 100% RDF | 0.21 | 0.19 | 0.09 | 0.29 | 0.24 | 0.21 | 0.10 | 0.31 |
| $T_3$: 125% RDF | 0.23 | 0.21 | 0.11 | 0.33 | 0.26 | 0.23 | 0.13 | 0.34 |
| $T_4$: 100% RDF + VAM | 0.22 | 0.20 | 0.11 | 0.32 | 0.25 | 0.22 | 0.12 | 0.33 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 0.27 | 0.24 | 0.13 | 0.35 | 0.29 | 0.26 | 0.15 | 0.37 |
| $T_6$: 75% RDF + VAM | 0.20 | 0.18 | 0.09 | 0.27 | 0.22 | 0.19 | 0.09 | 0.29 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 0.25 | 0.22 | 0.12 | 0.34 | 0.27 | 0.24 | 0.14 | 0.35 |
| **SEm (±)** | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 |
| **CD (P=0.05)** | NS | NS | NS | NS | NS | NS | NS | NS |
| **CV (%)** | 13.78 | 13.70 | 13.74 | 12.61 | 13.24 | 13.48 | 14.47 | 13.10 |

**Table 5. Effect of different levels of fertilizers in combination with biofertilizers on nitrogen uptake (kg ha$^{-1}$) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Knee high | Tasseling | Harvest | | Knee high | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 16.52 | 67.62 | 27.11 | 49.19 | 18.45 | 72.78 | 28.12 | 53.34 |
| $T_2$: 100% RDF | 28.86 | 134.31 | 47.72 | 73.32 | 32.87 | 140.89 | 53.36 | 93.66 |
| $T_3$: 125% RDF | 36.64 | 141.94 | 52.45 | 89.85 | 39.60 | 148.42 | 58.08 | 106.50 |
| $T_4$: 100% RDF + VAM | 35.55 | 139.55 | 51.14 | 87.04 | 38.48 | 143.30 | 57.12 | 103.74 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 41.65 | 166.49 | 63.14 | 101.99 | 46.17 | 174.69 | 69.79 | 120.55 |
| $T_6$: 75% RDF + VAM | 23.99 | 109.72 | 39.91 | 72.38 | 26.76 | 116.13 | 42.61 | 77.50 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 37.21 | 146.71 | 56.17 | 95.64 | 41.14 | 155.32 | 51.52 | 109.85 |
| **SEm (±)** | 2.20 | 9.93 | 4.04 | 5.02 | 2.53 | 10.29 | 4.33 | 5.49 |
| **CD (P=0.05)** | 6.76 | 27.61 | 12.44 | 15.46 | 7.80 | 31.70 | 13.33 | 16.91 |
| **CV (%)** | 12.36 | 13.38 | 14.59 | 11.12 | 12.66 | 13.18 | 14.14 | 10.04 |

**Table 6. Effect of different levels of fertilizers in combination with biofertilizers on phosphorus uptake (kg $ha^{-1}$) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Knee high | Tasseling | Harvest | | Knee high | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 1.79 | 6.74 | 2.11 | 5.81 | 3.34 | 8.73 | 5.03 | 6.86 |
| $T_2$: 100% RDF | 3.27 | 16.52 | 6.12 | 12.21 | 5.68 | 20.32 | 9.80 | 15.12 |
| $T_3$: 125% RDF | 4.45 | 18.85 | 8.39 | 15.67 | 8.94 | 29.18 | 13.65 | 20.28 |
| $T_4$: 100% RDF + VAM | 4.25 | 18.72 | 8.29 | 15.18 | 8.33 | 28.15 | 13.12 | 19.95 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 5.04 | 23.01 | 10.06 | 18.33 | 10.54 | 34.40 | 15.73 | 24.32 |
| $T_6$: 75% RDF + VAM | 2.62 | 14.84 | 4.36 | 9.11 | 5.34 | 17.18 | 7.11 | 12.33 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 4.53 | 20.85 | 9.44 | 16.59 | 9.56 | 31.28 | 14.92 | 21.29 |
| **SEm (±)** | 0.26 | 1.39 | 0.58 | 1.03 | 0.63 | 2.03 | 0.89 | 1.42 |
| **CD (P=0.05)** | 0.81 | 4.29 | 1.78 | 3.19 | 1.95 | 6.27 | 2.76 | 4.37 |
| **CV (%)** | 12.40 | 13.96 | 14.33 | 13.35 | 14.89 | 14.15 | 13.66 | 14.06 |

**Table 7. Effect of different levels of fertilizers in combination with biofertilizers on potassium uptake (kg ha$^{-1}$) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Knee high | Tasseling | Harvest | | Knee high | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 19.40 | 79.70 | 86.11 | 6.97 | 21.50 | 86.42 | 93.01 | 8.08 |
| $T_2$: 100% RDF | 32.61 | 141.76 | 155.92 | 14.32 | 37.03 | 152.80 | 164.14 | 20.45 |
| $T_3$: 125% RDF | 41.92 | 153.19 | 170.08 | 17.83 | 45.83 | 162.83 | 177.52 | 26.24 |
| $T_4$: 100% RDF + VAM | 39.98 | 147.76 | 164.23 | 17.42 | 44.55 | 153.75 | 170.60 | 25.57 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 45.47 | 174.22 | 194.07 | 21.23 | 50.22 | 188.26 | 205.42 | 29.88 |
| $T_6$: 75% RDF + VAM | 27.96 | 124.98 | 130.30 | 12.01 | 31.22 | 132.25 | 137.83 | 15.57 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 43.67 | 160.21 | 179.44 | 18.22 | 47.96 | 171.38 | 188.43 | 26.60 |
| **SEm (±)** | 1.81 | 10.41 | 9.98 | 1.28 | 1.90 | 11.45 | 12.31 | 1.60 |
| **CD (P=0.05)** | 5.56 | 26.58 | 30.76 | 3.93 | 5.85 | 35.28 | 37.93 | 4.94 |
| **CV (%)** | 8.94 | 12.71 | 11.10 | 13.94 | 8.37 | 13.10 | 13.04 | 13.06 |

**Table 8. Effect of different levels of fertilizers in combination with biofertilizers on sulphur uptake (g ha$^{-1}$) at different growth stages of maize**

| Treatments | *Kharif* (2020) | | | | *Kharif* (2021) | | | |
|---|---|---|---|---|---|---|---|---|
| | Knee high | Tasseling | Harvest | | Knee high | Tasseling | Harvest | |
| | | | Straw | Grain | | | Straw | Grain |
| $T_1$: Control | 1.61 | 5.78 | 3.19 | 8.15 | 1.81 | 6.55 | 3.80 | 8.99 |
| $T_2$: 100% RDF | 2.69 | 10.40 | 6.42 | 15.39 | 3.05 | 11.33 | 7.55 | 16.67 |
| $T_3$: 125% RDF | 3.65 | 12.99 | 8.96 | 18.51 | 3.95 | 14.49 | 10.66 | 19.74 |
| $T_4$: 100% RDF + VAM | 3.50 | 12.87 | 8.76 | 17.62 | 3.79 | 14.15 | 10.30 | 19.55 |
| $T_5$: 100% RDF + VAM+ *Azospirillum* + PSB | 4.57 | 16.53 | 10.33 | 21.86 | 4.60 | 17.30 | 12.36 | 23.98 |
| $T_6$: 75% RDF + VAM | 2.63 | 9.51 | 5.71 | 12.67 | 2.68 | 9.88 | 6.36 | 13.54 |
| $T_7$: 75% RDF + VAM + *Azospirillum* + PSB | 4.17 | 14.96 | 9.52 | 20.34 | 4.18 | 15.43 | 11.77 | 21.37 |
| **SEm (±)** | 0.36 | 1.20 | 0.53 | 1.41 | 0.27 | 1.05 | 0.70 | 1.46 |
| **CD (P=0.05)** | 1.01 | 3.71 | 1.63 | 4.34 | 0.82 | 3.23 | 2.14 | 4.50 |
| **CV (%)** | 14.24 | 14.09 | 12.14 | 14.93 | 13.52 | 14.28 | 13.43 | 14.29 |