



# Assessment of Different Nutrient Combination on the Performance of Maize (*Zea mays* L) in North Indian Plains

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

A field experiment was conducted during the kharif season of 2023 at the Agriculture Research Farm, Graphic Era Hill University, Uttarakhand. Surface soil (0-15 cm) of the experiment field was sandy loam in texture, low organic carbon (0.39%), medium in available nitrogen (157 kg h<sup>-1</sup>), medium in available phosphorus (15.5 kg ha<sup>-1</sup>) and medium in available potassium (112.6 kg ha<sup>-1</sup>)

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with neutral soil reaction (pH 7.4). The experiment consisted of eleven treatments viz., 100% NPK (T<sub>1</sub>), 100% N (T<sub>2</sub>), 100% P (T<sub>3</sub>), 100% K (T<sub>4</sub>), 100% NP (T<sub>5</sub>), 100% NK (T<sub>6</sub>), 100% PK (T<sub>7</sub>), 100% NPK + VC 5 t ha<sup>-1</sup> (T<sub>8</sub>), 100% + *Azotobacter* (T<sub>9</sub>), 100% + VC 5 t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>), Control (T<sub>11</sub>). Each treatment was replicated thrice and constituted total of 33 plots. The field experiment was laid out in a randomized block design (RBD). The variety used for the field experiment was K-55. The results of the field experiment reported that the effect of different treatments was significant on growth and productivity of maize. Significantly higher emergence count m<sup>-2</sup> (9 m<sup>-2</sup>) of maize was obtained with the application of 100% NPK + VC @ 5t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>). Maximum plant height (102.07 cm, 155.02 cm and 225.87 cm) was observed under treatment 100% NPK + VC @ 5t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>) at 30, 45 and 60 days of sowing, respectively. It also produced highest dry matter m<sup>-2</sup> (556.56 g, 1023.20 g, and 2062.00 g, respectively at 30 DAS, 45 DAS and 60 DAS). Application of vermicompost along with *Azotobacter* and chemical fertilizer produced maximum number of leaves per plant (4.05, 8.87 and 14.20 at 30 DAS, 45 DAS and 60 DAS, respectively). Application of 100% NPK + VC @ 5t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>) resulted in significant improvement in yield attributes and yield of maize compared to other treatments. The maximum grain yield (59.93 q ha<sup>-1</sup>) and straw yield (69.90q ha<sup>-1</sup>) was produced under 100% NPK + VC @ 5t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>). Moreover, adoption of different nutrient combinations resulted in improving the economic status of the farmer. Significantly higher B: C ratio of 1.90 was recorded for 100% NPK + VC @ 5t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>) and it was 14.45 % higher than that for 100 % NPK (T<sub>1</sub>). Hence, it is concluded that application of 100% NPK + VC 5 t ha<sup>-1</sup> + *Azotobacter* exhibited higher growth and yield along with B: C ratio.

**Keywords:** Maize; nutrient; vermicompost; azotobacter; optimizing; combination.

## 1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops and also known as “queen of cereals” due to its high productive potential compared to other cereal crop [12,1] It is a C4 plant, due to its ability to utilize solar radiation more efficiently even at higher radiation intensity [12]. Maize grain contains 70% carbohydrate, 10% protein, 4% oil, 10.4% albumin, 2.3% crude fiber, 1.4% ash. Sugar-rich varieties called sweet corn are usually grown for fresh consumption, while field-corn varieties are used for animal feed and as chemical feedstocks. Moreover, maize is also a major source of oil, gluten, and starch, which can be hydrolyzed and enzymatically treated to produce syrups, particularly high fructose corn syrup. The corn steep liquor, a plentiful watery byproduct of the maize wet milling process, is widely used in the biochemical industry and research purposes as a culture medium to grow many kinds of microorganisms. Its world average yield is 27.8 q ha<sup>-1</sup> maize ranks first among the cereals followed by rice, wheat, and millets; with average grain yield of 22.5, 6.6 q ha<sup>-1</sup>). In area, Maize is the third most important staple food respectively crop in the world after wheat, and rice regarding productivity. Worldwide maize is cultivated on approximately 177 mha area with production of 967 mt and productivity of 5.46 t ha<sup>-1</sup>. Similarly in the world,

USA, China, Brazil, India and Argentina are leading countries in maize production. In India, maize is cultivated on 10.43 mha area, with production and productivity of 32.35 mt and 2.12 t ha<sup>-1</sup>, respectively. Maize is grown mainly as a rainfed crop during rabi season with only 22.8% area under irrigated conditions. Karnataka, Maharashtra, Andhra Pradesh, and Madhya Pradesh and Uttar Pradesh are leading states in area, Andhra Pradesh, Karnataka, Maharashtra and Bihar in production and Tamil Nadu, Punjab, Andhra Pradesh and West Bengal have higher crop productivity.

Use of different sources of nutrients in an integrated manner helps to produce sustainable yields with good quality crops. Organic matter induces life into this inter mixture and promotes biological activity, vermicompost and farmyard manure are two examples of organic manures that are crucial parts of integrated nutrient management. Micronutrients are provided in trace amounts by organic manures, which are typically not provided by farmers as pure fertilizers [2]. Therefore, the only solution that should be supported in order to reduce input costs and enhance soil health is organic farming. By enhancing the physico-chemical characteristics of the soil, the use of organic manures like FYM and vermicompost not only helps to

sustain soil productivity but also increases the effectiveness of chemical fertilizers that are used by lowering chemical toxicity to the bacteria and so promoting their proliferation, it mitigates the negative effects of chemical fertilizers applied to the soil. Additionally, organic manure increases the soil's ability to store water and exchange cations which results in a more efficient supply of nutrients to crop plants and, ultimately, more profitable harvests [3]. Organic fertilizer, a soil improvement material, itself contains a large amount of organic matter, metabolites, and microorganisms, which could improve the recovery of soil nutrients and contribute to the dissolution and absorption of P by plants (Luo et al., 2019). Application of organic fertilizer alone insufficiently increases crop yield because nutrient content of organic fertilizer is unbalanced and if it is applied in a large quantity to balance nutrient supply the loss will increase. Therefore integrated plant nutrient management can minimize the problem. Application of mineral fertilizer in combination with locally available organic fertilizer to maintain soil fertility and to balance nutrient supply in order to increase crop yield. It is one of the best practices of plant nutrient management to take into consideration mineral fertilizer integration with organic sources of the plant nutrients to optimize social, economic, and environmental benefits of crop production.

The efforts are to be made to boost up to the yield per hectare of maize production through different nutrient combinations. Though the input management had been given due to importance still there is a need to quality and optimize the different nutrient sources of cereals crop.

## 2. MATERIALS AND METHODS

The present experiment is conducted at Agricultural Research Farm of Graphic Era Hill University; Dehradun Uttarakhand during kharif season of 2023 "Assessment of Different Nutrient Combination on the Performance of Maize (*Zea mays* L.) in North India Plains" The experimental site lies in region of foothills of Shivalik range of Himalayas, Dehradun. Geographically, it is situated at 30.34° N latitude, 78.02° E longitude and 64° m above mean sea level. Dehradun is characterized by humid subtropical climate with warm summer and severe cold winter. Generally, south-west monsoon sets in the second or third week of June and continues up to the end of

September. The highest temperature is found in the month of May- June and that of the lowest in December-January. The mean annual rainfall of this region is 2025 mm, of which 70% is received during the rainy season (July-September). Few showers may also be received during the winter months. Frost generally occurs towards the end of December and May continues till the end of January. Winters are very cold and continue from November to March. The daily average minimum temperature in the coldest month during winter varies from 1.0- 9.0°C and during summer, the maximum temperature varies from 30-43°C.

The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments were randomly allocated to different plots viz, 100% NPK (T<sub>1</sub>), 100% N (T<sub>2</sub>), 100% P (T<sub>3</sub>), 100% K (T<sub>4</sub>), 100% NP (T<sub>5</sub>), 100% NK (T<sub>6</sub>), 100% KP (T<sub>7</sub>), 100% NPK + Vermicompost 5 t ha<sup>-1</sup> (T<sub>8</sub>), 100% NPK + Biofertilizer 20g kg<sup>-1</sup> seed (T<sub>9</sub>), 100% NPK + Vermicompost 5 t ha<sup>-1</sup>+ Biofertilizer 20g kg<sup>-1</sup> seed (T<sub>10</sub>), Control (T<sub>11</sub>) each replicated thrice. In each plot ten plant taken randomly from the produce harvest from net plot (2m x 2m) for recording yield attributes (cob length, number of cobs per plant, number of grains<sup>-1</sup> and cob length), yield (grain, straw and biological yield) and economics (cost of cultivation, net return, gross return and benefit cost ratio). Benefit cost ratio was calculated using the following formula:

$$B:C = \frac{\text{Netreturn}}{\text{Coastofcultivation}}$$

The initial soil samples were collected from the experimental field at 0-15 cm depth. the experiment field was low organic carbon (0.39%), medium in available nitrogen(157 kg h<sup>-1</sup>), medium in available of phosphorus (15.5 kg h<sup>-1</sup>) and medium in available potassium (112.6 kg h<sup>-1</sup>) of with neutral soil reactions was sandy loam in texture, low organic carbon medium availability of nitrogen with neutral soil reaction (pH 7.4).

## 3. RESULTS AND DISCUSSION

### 3.1 Emergence Count and Plant Height

The different nutrient combination treatment significantly affected the emergence count and plant height of maize. The result showed that maximum emergence count per m<sup>-2</sup> (9.0) was obtained with the application of 100% NPK +

Biofertilizer + VC @ 5 t ha<sup>-1</sup> (T<sub>10</sub>). It was statistically at par with 100% NPK + Biofertilizer, 100% NPK +VC @ 5 t ha<sup>-1</sup> (T<sub>10</sub>) and significantly higher than the rest of the treatments. The results showed that 100% NPK + Azotobacter + VC @ 5t ha<sup>-1</sup> increased emergence count m<sup>-2</sup> by 34% and 200% over 100% NPK (T<sub>1</sub>) and control (T<sub>11</sub>), respectively. as they reported maximum emergence count (10) with combined application of 100% RDF + vermicompost + biofertilizer.

The plant height of maize increased progressively with advancement in crop growth up till harvest irrespective of the treatment. The data enumerated in Table 1. reveals that plant height of maize varied significantly under the influence of different treatments at all the crop growth stages. The result shows that maximum plant height (102.0 cm, 155.0 cm and 225.8, respectively at 30, 45 & 60 DAS) was obtained with the application of 100% NPK +VC @ 5t ha<sup>-1</sup> + Azotobacter (T<sub>10</sub>). At 30 and 45 DAS, it was statistically at par with 100% NPK + Azotobacter (T<sub>9</sub>), 100 % NPK + VC @ 5t ha<sup>-1</sup> (T<sub>8</sub>), 100% NPK (T<sub>1</sub>), 100% NP (T<sub>5</sub>) and 100% NK (T<sub>6</sub>) and significantly higher than rest of the treatments. At 60 DAS, it was statistically at par with 100% NPK + Azotobacter (T<sub>9</sub>) and 100 % NPK + VC @ 5t ha<sup>-1</sup> (T<sub>8</sub>) and significantly higher than the rest of the treatments. Application of 100% NPK +VC @ 5t ha<sup>-1</sup> + Azotobacter (T<sub>10</sub>) increased plant height by 137% over control and 13.2% over 100% NPK (T<sub>1</sub>). It might be possibly due to influence of vermicompost and biofertilizer in improving soil organic matter and microbial activity, leading to long-term soil fertility which improves the

availability and essential micro-nutrient uptake, water retention, and water holding capacity which help to improved soil health increase plant height. Similar research findings in G. Bharathan and S. M. Suresh Kumar [11] with application of 100% RDF + vermicompost @ 5 t ha<sup>-1</sup> + soil application of azospirillum @ 2.

### 3.2 Dry Matter Accumulation m<sup>-2</sup> and Number of Leaves Per Plant

The dry matter of maize increased progressively with advancement in crop growth up till harvest irrespective of the treatment. The data enumerated in Table 2. indicates that dry matter accumulation of maize varied significantly under the influence of different treatments at all the crop growth stages. The results shows that maximum dry matter accumulation per m<sup>-2</sup> (556.56 gm, 1023.20 gm and 2062.00 gm, respectively at 30, 45 & 60 DAS) was obtained with the application of 100% NPK + Biofertilizer + VC @ 5t ha<sup>-1</sup> (T<sub>10</sub>). It is statistically at par with 100% NPK+ Biofertilizer (T<sub>9</sub>), 100% NPK + VC @ 5 t ha<sup>-1</sup> (T<sub>8</sub>) and significantly higher than the rest of the treatments. Minimum dry matter g per plant (235.6 g, 476.4 g, and 772.8 g at 30, 45 and 60 DAS, respectively) was recorded under control (T<sub>11</sub>) at all crop growth stages. It might be due to Azotobacter being able to enhance the plant's ability to tolerate various abiotic stresses, such as drought and salinity. This resilience helps maintain growth and productivity under adverse conditions due to adverse effects on NPK, which provide an immediate supply of nutrients and increases the weight of plants.

**Table 1. Effect of different nutrient combination emergence m<sup>-2</sup> and plant height at different crop growth stages**

| Treatments      | Emergence Count m <sup>-2</sup> | Plant height (cm) |         |         |
|-----------------|---------------------------------|-------------------|---------|---------|
|                 |                                 | 30 DAYS           | 45 DAYS | 60 DAYS |
| T <sub>1</sub>  | 6.6                             | 94.3              | 144.9   | 199.50  |
| T <sub>2</sub>  | 5.6                             | 87.6              | 94.5    | 176.60  |
| T <sub>3</sub>  | 3.3                             | 80.0              | 98.7    | 184.37  |
| T <sub>4</sub>  | 3.6                             | 75.0              | 85.4    | 173.63  |
| T <sub>5</sub>  | 4.6                             | 92.5              | 141.5   | 195.73  |
| T <sub>6</sub>  | 5.6                             | 91.9              | 141.2   | 189.37  |
| T <sub>7</sub>  | 4.6                             | 80.3              | 117.5   | 181.97  |
| T <sub>8</sub>  | 8.0                             | 96.8              | 148.1   | 212.60  |
| T <sub>9</sub>  | 8.5                             | 98.1              | 150.2   | 217.37  |
| T <sub>10</sub> | 9.0                             | 102.0             | 155.0   | 225.87  |
| T <sub>11</sub> | 3.0                             | 54.3              | 80.3    | 93.47   |
| SEm±            | 0.4                             | 3.4               | 3.6     | 7.8     |
| CD ( at 5 %)    | 1.1                             | 10.1              | 10.7    | 23.1    |

**Table 2. Effect of different nutrient combination on dry matter accumulation m<sup>-2</sup> and number of leaves at different crop growth stages**

| Treatment       | Dry matter accumulation m <sup>-2</sup> |         |         | No. of leaves per plant |         |         |
|-----------------|---|---------|---------|-------------------------|---------|---------|
|                 | 30 DAYS                                 | 45 DAYS | 60 DAYS | 30 DAYS                 | 45 DAYS | 60 DAYS |
| T <sub>1</sub>  | 490.8                                   | 861.6   | 1379.6  | 3.7                     | 7.6     | 13.0    |
| T <sub>2</sub>  | 425.2                                   | 817.6   | 1357.9  | 3.4                     | 7.2     | 12.6    |
| T <sub>3</sub>  | 398.8                                   | 798.0   | 1239.3  | 2.0                     | 6.6     | 11.2    |
| T <sub>4</sub>  | 410.8                                   | 777.60  | 1232.2  | 1.8                     | 7.2     | 11.5    |
| T <sub>5</sub>  | 398.8                                   | 838.4   | 1422.2  | 3.5                     | 7.4     | 12.9    |
| T <sub>6</sub>  | 438.8                                   | 826.8   | 1433.6  | 3.4                     | 7.3     | 12.9    |
| T <sub>7</sub>  | 464.8                                   | 803.60  | 1736.8  | 2.0                     | 6.7     | 12.5    |
| T <sub>8</sub>  | 486.8                                   | 960.40  | 1722.4  | 3.8                     | 8.2     | 13.3    |
| T <sub>9</sub>  | 524.5                                   | 989.0   | 1979.6  | 3.9                     | 8.6     | 13.9    |
| T <sub>10</sub> | 556.5                                   | 1023.2  | 2062.0  | 4.0                     | 8.8     | 14.2    |
| T <sub>11</sub> | 235.6                                   | 476.4   | 772.8   | 1.0                     | 5.8     | 8.5     |
| SEm±            | 22.0                                    | 24.1    | 58.1    | 0.1                     | 0.5     | 0.4     |
| CD (at 5 %)     | 64.9                                    | 71.1    | 171.4   | 0.5                     | 1.4     | 1.3     |

The data with respect to the number of leaves per plant clearly indicates the influence of different treatments. The results show that the maximum number of leaves (4.0, 8.6, and 14.2 respectively at 30, 45 & 60 DAS) was obtained with the application of 100% NPK + VC @ 5t ha<sup>-1</sup> + Azotobacter (T<sub>10</sub>). At 30 and 45 DAS, it was statistically at par with 100% NPK + Biofertilizer (T<sub>9</sub>), 100 % NPK + VC @ 5t ha<sup>-1</sup> (T<sub>8</sub>), 100% NPK (T<sub>1</sub>), 100% NP (T<sub>5</sub>) and 100% NK(T<sub>6</sub>) and significantly higher than rest of the treatments. However, at 60 DAS, it was statistically at par with 100% NPK + Biofertilizer (T<sub>9</sub>) and 100% NPK + VC @ 5t ha<sup>-1</sup> (T<sub>8</sub>) but significantly higher over the rest of the treatments. Minimum number of leaves per plant (1.0, 5.8 and 8.5 at 30, 45 and 60 DAS, respectively) was recorded under control (T<sub>11</sub>) at all crop growth stages. It may be attributed to the assured and continuous supply of all the essential nutrients in adequate amounts through combined application of synthetic fertilizers, vermicompost and biofertilizers. Additionally, continuous supply of nitrogen affects photosynthetic rate which helps to increase the number of leaves per plant vigorously.

### 3.3 Cob Length and Number of Cob Per Plant Yield Attributes of Maize

The result shows that maximum cob length (14.9 cm) was obtained with the application of 100% NPK + Biofertilizer + VC @ 5t ha<sup>-1</sup> (T<sub>10</sub>) but it was statistically at par with (100% NPK Biofertilizer T<sub>9</sub> and 100% NPK + VC @ 5 t ha<sup>-1</sup> T<sub>8</sub>) and significantly higher than rest of the treatments. The minimum cob length (5.8 cm) was recorded under control (T<sub>11</sub>). Minimum cob lent found in

this result was not conformity with Jeevabharathi et al. [4]with application of 100% recommended dose of fertilizer + vermicompost @ 5 t ha<sup>-1</sup> + seed treatment (Azospirillum) @ 600 g ha<sup>-1</sup> + soil application (Azospirillum) @ 2000 g ha<sup>-1</sup> (26.0 cm).

Data pertaining to the number of cobs/plants of maize as recorded under various treatments are presented in Table 3. The perusal of data reveals that maximum number of cob/plant (2.67) was obtained with the application of 100% NPK + Biofertilizer + VC @ 5t ha<sup>-1</sup> (T<sub>10</sub>) but it was statistically at par with 100% NPK Biofertilizer (T<sub>9</sub>) and 100% NPK + VC @ 5 t ha<sup>-1</sup> (T<sub>8</sub>) and significantly higher than rest of the treatments. The minimum number of cob per plant (1.0) was recorded under control (T<sub>11</sub>) treatment. It might be due to imbalances in the nutrients nitrogen (N), phosphorus (P), and potassium (K) can significantly affect the growth and health of corn and decrease the cob number in plant which is not benefit for better yield that's why proper NPK balance ensures efficient photosynthesis, energy transfer, and overall plant health.

### 3.4 Biological Yield, Grain Yield, Stover Yield and Harvest Index of Maize

The result reveals that the biological yield of maize was influenced significantly due to different treatments. Maximum biological yield (129.8 q ha<sup>-1</sup>) was obtained with the application of 100% NPK + Biofertilizer + VC @ 5t ha<sup>-1</sup> (T<sub>10</sub>). It was found statistically at par with 100% NPK Biofertilizer (T<sub>9</sub>), 100% NPK + VC @ 5 t ha<sup>-1</sup> (T<sub>8</sub>) and significantly higher than the rest of the treatments. Percent increase of 18.8% and 126%

**Table 3. Effect of different nutrient combination on cob length (cm) and number of cob per plants on yield attributes**

| Treatments      | Cob length(cm) | Cobs plant <sup>-1</sup> |
|-----------------|----------------|--------------------------|
| T <sub>1</sub>  | 12.9           | 1.5                      |
| T <sub>2</sub>  | 8.5            | 1.3                      |
| T <sub>3</sub>  | 8.0            | 1.2                      |
| T <sub>4</sub>  | 7.2            | 1.3                      |
| T <sub>5</sub>  | 12.2           | 1.5                      |
| T <sub>6</sub>  | 11.8           | 1.7                      |
| T <sub>7</sub>  | 10.7           | 1.5                      |
| T <sub>8</sub>  | 13.9           | 2.5                      |
| T <sub>9</sub>  | 14.2           | 2.6                      |
| T <sub>10</sub> | 14.9           | 2.6                      |
| T <sub>11</sub> | 5.8            | 1.0                      |
| SEm±            | 0.5            | 0.09                     |
| CD ( at 5 %)    | 1.5            | 0.2                      |

for biological yield was obtained with application of 100% NPK + Biofertilizer + VC @ 5t ha<sup>-1</sup> (T<sub>10</sub>) over 100% NPK (T<sub>1</sub>) and control (T<sub>11</sub>), respectively. Minimum biological yield of 55.5 q ha<sup>-1</sup> was recorded control (T<sub>11</sub>). It might be possible due to the application of recommended doses of NPK in addition to vermicompost and biofertilizer that gave the best results with respect to growth and yield attributes of crops. The application of nitrogen from chemical fertilizers promoted the plant growth, whereas organic sources of nutrition improved the growth at later stages. Application of vermicompost exerted the positive influence on growth of plants owing to presence of readily available nutrients and growth enhancing substances, which resulted in better crop production and biofertilizers, not allowing pathogens to flourish, they are also eco-friendly and cost-effective. Similar findings were observed by Singh et al. [5] 75% RDF + Vermicompost (5t ha<sup>-1</sup>) + FYM (5t ha<sup>-1</sup>) + Azotobacter gave the highest biological yield of 207.7 q ha<sup>-1</sup>.

The result shows that maximum grain yield (59.9 q ha<sup>-1</sup>) was observed with the application of 100% NPK + Azotobacter + VC @ 5t ha<sup>-1</sup> (T<sub>10</sub>). It was statistically at par with (100% NPK+ Azotobacter (T<sub>9</sub>), 100% NPK + VC @ 5 t/ha (T<sub>8</sub>) and significantly higher than the rest of the treatments. Application of 100% NPK+ Azotobacter + VC @ 5t ha<sup>-1</sup> increased grain yield by 14.87% and 135.66% over 100% NPK (T<sub>1</sub>) and 100% NP (T<sub>4</sub>), respectively. It may be due to the fact that organic manures and biofertilizers could have provided the required amount of available nutrients along with chemical fertilizers and improved chemical and biological properties of soil which ultimately reflected in increasing the

growth parameters as well as yield attributing characteristics and which leads to increase in yield. Azotobacter promotes plant growth by several mechanisms including N-fixation, phytohormone production such as auxin, gibberellins, cytokines, nitric oxide as signals of plant growth promotion. Similarly findings were observed by Singh et al. [5] 75% RDF + vermicompost (5t ha<sup>-1</sup>) + FYM (5t ha<sup>-1</sup>) + azotobacter with grain yield (63.7 q ha<sup>-1</sup>). The minimum grain yield (11.6 q/ha) was recorded in control (T<sub>11</sub>).

The result shows that maximum stover yield (69.9 q ha<sup>-1</sup>) was obtained with the application of 100% NPK + Azotobacter + VC @ 5t/ha (T<sub>10</sub>). It was statistically at par with (100% NPK+ Azotobacter (T<sub>9</sub>), 100% NPK + VC @ 5 t/ha (T<sub>8</sub>) and significantly higher than the rest of the treatments. Percent increase of 29.13% and 120.71% was observed with application of 100% NPK + Azotobacter + VC @ 5t ha<sup>-1</sup> compared to 100% NPK (T<sub>1</sub>) and control (T<sub>11</sub>), respectively. The minimum stover yield (31.6 q ha<sup>-1</sup>) was recorded under control (T<sub>11</sub>). Similar finding was observed by Jeevabharathi et al. [4] application of 100% RDF + vermicompost @ 5t ha<sup>-1</sup> + seed treatment (*Azospirillum*) @ 600 g/ha + soil application (*Azospirillum*) @ 2000 g/ha gave higher stover yield (94.3 q ha<sup>-1</sup>).

Data related to the harvest index as influenced by different treatments is presented in Table 4. The perusal of data shows that harvest index did not vary significantly under the influence of different treatments. However, the maximum harvest index (52.1%) was obtained with the application of 100% NPK (T<sub>1</sub>). Minimum harvest index (44.4%) was obtained with the application of control (T<sub>11</sub>).

**Table 4. Effect of different nutrient combination on biological yield, grain yield, stover yield and harvest index% of maize**

| Treatments      | Biological yield (q ha <sup>-1</sup> ) | Grain yield (q ha <sup>-1</sup> ) | Stover yield (q ha <sup>-1</sup> ) | Harvest index (%) |
|-----------------|--|-----------------------------------|------------------------------------|-------------------|
| T <sub>1</sub>  | 109.2                                  | 52.1                              | 57.1                               | 47.7              |
| T <sub>2</sub>  | 89.3                                   | 42.9                              | 46.4                               | 48.0              |
| T <sub>3</sub>  | 87.5                                   | 42.0                              | 45.4                               | 48.0              |
| T <sub>4</sub>  | 89.1                                   | 39.9                              | 49.2                               | 44.7              |
| T <sub>5</sub>  | 92.8                                   | 45.8                              | 47.0                               | 49.3              |
| T <sub>6</sub>  | 92.6                                   | 44.7                              | 47.9                               | 48.2              |
| T <sub>7</sub>  | 96.6                                   | 43.2                              | 53.4                               | 44.7              |
| T <sub>8</sub>  | 121.5                                  | 57.3                              | 64.1                               | 47.1              |
| T <sub>9</sub>  | 124.6                                  | 57.7                              | 66.8                               | 46.3              |
| T <sub>10</sub> | 129.8                                  | 59.9                              | 69.9                               | 46.1              |
| T <sub>11</sub> | 57.1                                   | 25.4                              | 31.6                               | 44.5              |
| SEm±            | 2.97                                   | 0.9                               | 3.0                                | 2.0               |
| CD (5 %)        | 8.7                                    | 2.9                               | 9.09                               | N/S               |

**Table 5. Effect of different nutrient combinations on economics of maize**

| Treatments      | Cost of cultivation | Gross return | Net return | Benefit cost |
|-----------------|---------------------|--------------|------------|--------------|
| T <sub>1</sub>  | 43086.0             | 112985.6     | 69899.6    | 1.6          |
| T <sub>2</sub>  | 34164.0             | 89365.7      | 55201.7    | 1.6          |
| T <sub>3</sub>  | 39581.0             | 87624.9      | 48043.9    | 1.2          |
| T <sub>4</sub>  | 33751.0             | 83486.4      | 49735.4    | 1.4          |
| T <sub>5</sub>  | 41664.0             | 95279.8      | 53615.8    | 1.2          |
| T <sub>6</sub>  | 36534.0             | 93160.6      | 56626.6    | 1.5          |
| T <sub>7</sub>  | 41251.0             | 90458.0      | 49207.0    | 1.1          |
| T <sub>8</sub>  | 51586.0             | 119537.7     | 67951.6    | 1.3          |
| T <sub>9</sub>  | 43678.0             | 101145.4     | 101145.4   | 1.7          |
| T <sub>10</sub> | 52178.0             | 125099.7     | 72373.7    | 1.9          |
| T <sub>11</sub> | 24900.0             | 53187.5      | 28287.5    | 1.1          |
| SEm±            | -                   | 1964.9       | 1964.9     | 0.07         |
| CD (at 5 %)     | -                   | 5796.5       | 5796.5     | 0.2          |

### 3.5 Economics of Maize

The maximum cost of cultivation (₹ 52178.0 ha<sup>-1</sup>) was obtained with the 100% NPK + VC @ 5t ha<sup>-1</sup> + Azotobacter (T<sub>10</sub>). This is because of the additional cost of synthetic fact, vermicompost and biofertilizer. The minimum cost of cultivation amounting to ₹ 24900.0 ha<sup>-1</sup> was calculated under control (T<sub>11</sub>) because of no fertilizer application. Highest cost of cultivation was recorded in treatment (T<sub>10</sub>) because it involves the use of 100% NPK along with vermicompost and biofertilizer and minimum cost of cultivation was recorded in (T<sub>11</sub>) as this treatment included no application of fertilizers.

The perusal of data indicates Table 5. shows that gross return of maize cultivation varied significantly under the influence of different treatments. Application of 100% NPK + VC @ 5t ha<sup>-1</sup> + Azotobacter (T<sub>10</sub>) resulted in maximum gross return (₹125099.7). It was found to be

significantly higher than control (T<sub>1</sub>), 100% NPK (T<sub>1</sub>), 100% NPK + VC @ 5t ha<sup>-1</sup> (T<sub>8</sub>), 100% NPK + Azotobacter (T<sub>9</sub>) and statistically at par with the rest of the treatments. Gross return increased by 10.72% with the application of 100% RDF + VC @ 5t ha<sup>-1</sup> + Azotobacter (T<sub>10</sub>) compared to 100% RDF (T<sub>1</sub>).

The data enumerated in Table 5. reveals that maximum net return (₹101145.4 ha<sup>-1</sup>) was obtained with the application of 100% NPK + Azotobacter (T<sub>9</sub>). It was found to be significantly higher than control (T<sub>1</sub>), 100% NPK (T<sub>1</sub>), 100% NPK + VC @ 5t ha<sup>-1</sup> (T<sub>8</sub>) and 100% NPK + VC 5 t ha<sup>-1</sup> + Azotobacter (T<sub>10</sub>). Minimum net return (₹28287.5 ha<sup>-1</sup>) was found in control (T<sub>11</sub>). Higher net return under these treatments shows that these treatments accrued high gross return with a lower or similar cost of production. Higher net return under these treatments shows that these treatments accrued high gross return with a lower or similar cost of production. The results

are in conformity with Tomar et al. [6] as they recorded the highest net return (₹36073.5 ha<sup>-1</sup>) with application 100% NPK + 5 t FYM + *Azotobacter* + PSB.

Data presented in Table 5. shows that maximum B:C ratio (1.9) was obtained for 100% NPK + VC @ 5t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>). The result showed that Application of 100% NPK + VC @ 5t ha<sup>-1</sup> + *Azotobacter* (T<sub>10</sub>) was statically at par with Application 100% NPK + *Azotobacter* (T<sub>9</sub>). Percentage increased by 43.9% and 14.4% with application of 100% NPK + VC 5 t ha<sup>-1</sup> (T<sub>8</sub>) and 100% NPK (T<sub>1</sub>). Minimum benefit cost found in treatment 100% P (T<sub>4</sub>) 1.2. This may be due to the combination of treatment giving better yield. The findings align with that of Joshi et al. [7] registered maximum value of B: C ratio (1.9) with the application of 100% NPK + seed inoculation *Azotobacter*.

#### 4. CONCLUSION

The results obtained from the current study led to the conclusion that the combined application of 100% NPK along with vermicompost @ 5t ha<sup>-1</sup> and *Azotobacter* @ 20 g kg<sup>-1</sup> seed resulted in enhanced plant growth and increased yield, accompanied by a higher benefit-cost ratio (B: C ratio). This outcome may be attributed to the improved nutrient provisioning achieved through integrating different nutrient sources which facilitated optimal growth and yielded the highest harvest. Different nutrient management presents a promising and sustainable approach to modern agriculture. By judiciously combining organic and inorganic nutrient sources, this practice ensures a healthy crop yield. As we face the challenges of feeding a growing global population while conserving our ecosystems, integrated nutrient management stands as a vital step towards achieving both agricultural productivity and ecological balance.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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