
**E-ISSN:** 2618-0618
**P-ISSN:** 2618-060X

www.agronomyjournals.com
2024; SP-7(7): 683-686
Received: 02-06-2024
Accepted: 07-07-2024

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# Effect of different levels of NPK, sulphur and *Azotobacter* on the physico-chemical properties of soil, growth and yield attributes of mustard crop (*Brassica juncea* L.) *var*. T-59 black gold

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**DOI:** https://doi.org/10.33545/2618060X.2024.v7.i7Sj.1163

## Abstract
The field experiment was carried out at central research farm of department of soil science and agricultural chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during rabi season 2023-24. The texture of the soil in the experimental region was sandy loam. The design was set up using randomized block design, with two levels of sulphur (50 & 100%), *Azotobacter*, and NPK (80:40:40) at different levels. The treatment $T_9$ (@100% NPKS +@100% *Azotobacter*) gave the best results in terms of plant height, number of siliqua plant-1, and total mustard yield. It also showed a slight decrease in pH, bulk density, and particle density; however, there was a significant increase in pore space, water holding capacity, EC, organic carbon, available nitrogen, phosphorus, and potassium, as well as plant growth and yield attributes. There was no discernible difference in the growth and production of mustard under control. The use of organic manures, as well as their blend with complete NPK, significantly increases the characteristics of growth and total yield attributes of mustard.

**Keywords:** Mustard, NPK, sulphur, *Azotobacter*

## Introduction
Soil health is considered as “the state of a soil at a particular time, equivalent to the dynamic soil properties that changes in short term while soil quality may be considered as soil usefulness for a particular purpose over a long-time scale, equivalent to intrinsic or static soil quality” (Goswami, 2006) [3]. The other terms used are soil fertility and soil productivity. Soil fertility is inherent property of soil influenced by physical, biological and chemical factors of the soil & is related to plant nutrient management whereas soil productivity is capacity of soil to support crop growth. Typically, 17 essential nutrients are required for plant metabolism and for completion of plants life cycle. So, identification of the deficiency of any particular nutrient and amendment by supplying the right quantity it becomes necessary to perform soil analysis. These essential nutrients for plant growth are classified into: macronutrients which are required in more quantities and micronutrients that are required in relatively smaller quantities. Macronutrients include C, H, O, N, P, K, Ca, Mg, and S. Carbon, hydrogen, and oxygen are supplied through carbon dioxide ($CO_2$) and water from atmosphere. Remaining six nutrients are further divided into primary and secondary nutrients. *Azotobacter* is a free living heterotrophic nitrogen fixing bacteria encounters in neutral to alkaline soil conditions not only provides nitrogen, but produce a variety of growth promoting substances. The *Azotobacter* is capable of converting nitrogen to ammonia, which in turn is taken up by the plants (Kamil, *et al.*, 2008) [5]. *Azotobacter* sp. can also produce antifungal compounds to fight against many plant pathogens. *Azotobacter* is a group of free living aerobic nitrogen fixing bacteria which can minimize 10 to 20% use of nitrogenous fertilizers. *Brassica* spp., commonly known as rapeseed-mustard, plays an important role in the Indian economy by providing edible oils, vegetables, condiments and animal feed Jat *et al.*, (2019) [4]. Nine oilseeds are the primary sources of vegetable oil in India. Among them soybean (39%), groundnut (26%) and rapeseed-mustard (24%) contribute more than 88% of total oilseeds production in the country.

However, rapeseed mustard (31%) contributes maximum in terms of edible oil production followed by soybean {26%) and groundnut (25%) in the country MAFW (2019) [7].

Nitrogen is the most important nutrient, which determines the growth of the mustard crop and increases the amount of protein and the yield. Phosphorus and potash are known to be efficiently utilized in the presence of nitrogen. It promotes flowering, setting of siliqua and in increase the size of siliqua and yield. Sulphur is also an important nutrient and plays an important role in physiological functions like synthesis of cystein, methionine, chlorophyll and oil content of oil seed crops. It is also responsible for synthesis of certain vitamins (B, biotin and thiamine), metabolism of carbohydrates, proteins and oil formation of flavoured compounds in crucifers. *Brassica* has the highest sulphur requirement sowing to the presence of sulphur rich glucosinolates. (Bharose *et al*., 2010) [1].

Phosphorus is an element for Toria and mustard. Several scientists of the world have reported that the Toria gives significant response of added phosphorus deficient soils. Phosphorus is generally deficient in majority of our Indian soils and need much attention for maintenance of soil fertility. Several experiments have been conducted under varying agro-climatic conditions by research of different countries. They have reported that phosphorus application in general had beneficial Effect in imparting plant vagour and resistance of plants, against insect pest and disease, and increasing the vegetative growth and seed yield of Toria and mustard. When Phosphorus was applied in conjunction with nitrogen and potash, there was significant increase in the yield of Toria and mustard.

Potassium is one of the seventeen elements which are essential for growth and development of plants. Mustard is an important oil seed crop of arid and semi-arid region. Potassium is required for improving the yield and quality of different crops becouse of its effect on photosynthesis, water use efficiency and plant tolerance to diseases, drought and cold as well for making the balance between protein and carbohydrates. (Singh *et al*., 2010) [13].

## Materials and Methods

During the Rabi Season of 2023-2024, the research was conducted at the Soil Science Research Farm, Department of Soil Science and Agricultural Chemistry Sam Higginbottom University of Agriculture, Technology and Sciences, Naini Agricultural Institute, Prayagraj. Prayagraj district, with its exceptionally hot summers and relatively chilly winters, embodies the subtropical belt of South East Uttar Pradesh in terms of agroclimatology. The location's highest temperature is between 46 °C and 48 °C, with rare dips below 4 °C or 5 °C. There was a 20-94% variation in the relative humidity. This location receives around 1100 mm of rain on average each year. Three levels of inorganic fertilizer sulphur (50 & 100%), *Azotobacter*, and NPK (80:40:40) were used in the experiment, which was conducted using a Randomized Block Design (RBD). Each treatment was replicated three times. $T_1$-[@0% NPKS +@0% *Azotobacter*], $T_2$-[@0% NPKS +@50% *Azotobacter*], $T_3$-[@0% NPKS+@100% *Azotobacter*], $T_4$-[@50% NPKS +@0% *Azotobacter*], $T_5$-[@50% NPKS +@50% *Azotobacter*], $T_6$-[@50% NPKS +@100% *Azotobacter*], $T_7$-[@100% NPKS +@0% *Azotobacter*], $T_8$-[@100% NPKS +@50% *Azotobacter*] and $T_9$-[@100% NPKS +@100% *Azotobacter*] were the treatments. Characteristics of growth and yield were noted during the trial. The inorganic nutrients came from rhizobium, urea, SSP, MOP, and micronutrients, in that order.

## Results and Discussions

After harvesting the shows that soil bulk density was found to be non-significant by organic and inorganic. The maximum soil bulk density at 0-15 to 15-30 cm soil depth was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*] which was 1.38 and 1.41 Mg m-3 and minimum soil bulk density was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 1.20 and 1.23 Mg $m^{-3}$. Similar results have also been recorded by Shilpa and Dongale (2011) [12]. The maximum soil particle density at 0-15 to 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 2.63 and 2.62 Mg $m^{-3}$ and minimum soil particle density was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*] which was 2.43 and 2.42 Mg $m^{-3}$. Similar results have also been recorded by Shilpa and Dongale (2011) [12]. The maximum soil % pore space at 0-15 to 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*], which was 49.26 and 47.26% and minimum soil % pore space was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 43.74 and 41.69%. The maximum soil % WHC at 0-15 to 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*], which was 41.79 and 44.41% and minimum soil % WHC was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 36.60 and 38.77%. Similar results have also been recorded by Shilpa and Dongale (2011) [12]. The maximum soil pH at 0-15 to 15-30 cm soil depth was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 6.94 and 7.07 and minimum soil pH was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 6.66 and 6.79. Similar results have also been recorded by Nagar *et al*. (2015) [8]. The maximum soil EC (dS $m^{-1}$) at 0-15 cm and 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 0.42 and 0.37 Mg $m^{-1}$ and minimum was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*] which was 0.37 and 0.28 Mg $m^{-1}$. Similar results have also been recorded by Nagar *et al.* (2015) [8].

**Table 1:** Physical properties, pH and EC of soil sample after harvesting of mustard.

| Treatments combination | Bulk density (Mg $m^{-3}$) | | Particle density (Mg $m^{-3}$) | | % pore space | | WHC(%) | | pH(1:2) | | EC (dS $m^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-15 Cm | 15-30 cm | 0-15 Cm | 15-30 cm | 0-15 Cm | 15-30 cm | 0-15 Cm | 15-30 cm | 0-15 cm | 15-30 cm | 0-15 Cm | 15-30 cm |
| $T_1$ [@0% NPKS +@0% *Azotobacter*] | 1.38 | 1.41 | 2.43 | 2.42 | 43.74 | 41.69 | 36.6 | 38.77 | 6.94 | 7.07 | 0.37 | 0.28 |
| $T_2$ [@0% NPKS +@50% *Azotobacter*] | 1.34 | 1.37 | 2.46 | 2.46 | 45.57 | 43.57 | 38.47 | 40.44 | 6.91 | 7.04 | 0.34 | 0.3 |
| $T_3$ [@0% NPKS +@100% *Azotobacter*] | 1.28 | 1.31 | 2.52 | 2.51 | 46.74 | 44.74 | 39.46 | 41.46 | 6.88 | 7.01 | 0.4 | 0.33 |
| $T_4$ [@50% NPKS +@0% *Azotobacter*] | 1.33 | 1.36 | 2.45 | 2.45 | 44.45 | 42.45 | 37.35 | 39.35 | 6.89 | 7.02 | 0.39 | 0.34 |
| $T_5$ [@50% NPKS +@50% *Azotobacter*] | 1.27 | 1.3 | 2.5 | 2.49 | 46.11 | 44.11 | 38.96 | 40.96 | 6.87 | 7.00 | 0.42 | 0.33 |
| $T_6$ [@50% NPKS +@100% *Azotobacter*] | 1.23 | 1.26 | 2.55 | 2.55 | 47.84 | 45.84 | 40.73 | 42.73 | 6.83 | 6.96 | 0.41 | 0.35 |
| $T_7$ [@100% NPKS +@0% *Azotobacter*] | 1.29 | 1.32 | 2.5 | 2.5 | 44.91 | 42.91 | 38.28 | 40.28 | 6.85 | 6.98 | 0.39 | 0.35 |
| $T_8$ [@100% NPKS +@50% *Azotobacter*] | 1.24 | 1.28 | 2.57 | 2.56 | 47.23 | 45.23 | 41.4 | 43.4 | 6.81 | 6.94 | 0.43 | 0.36 |
| $T_9$ [@100% NPKS +@100% *Azotobacter*] | 1.2 | 1.23 | 2.63 | 2.62 | 49.26 | 47.26 | 41.79 | 44.41 | 6.66 | 6.79 | 0.42 | 0.37 |
| F- test | NS | NS | NS | NS | S | S | S | S | NS | NS | S | S |
| S. Ed. (±) | 0.588 | 1.618 | 0.688 | 1.718 | 0.67 | 0.627 | 0.67 | 0.627 | 0.013 | 0.012 | 0.313 | 0.312 |
| C. D. (P = 0.05) | 1.235 | 3.398 | 1.445 | 3.608 | 1.408 | 1.316 | 1.408 | 1.316 | 0.026 | 0.026 | 0.656 | 0.656 |

The data recorded on % organic carbon was recorded at 0-15 and 15-30 cm soil depth. The result of the data shows that soil % organic carbon was found to be significant by organic and inorganic. The maximum soil % organic carbon at 0-15 and 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*], which was 0.78 and 0.72 and minimum was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 0.70 and 0.66. Similar results have also been recorded by Kumar *et al.* (2011) and Nagar *et al.* (2015) [8]. The maximum soil available nitrogen (kg $ha^{-1}$) at 0-15 and 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 288.15 and 283.49 and minimum was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 218.86 and 214.56. Higher available nitrogen content under integrated application of organics and inorganics may be due to effect of organics applied, which might improve microbial population rapidly, facilitated the conversion of soil native organic nitrogen to mineral nitrogen (Parihar, 2016; Rajkhowa *et al*., 2003) [10, 11], reduced the loses of applied mineral nitrogen by formation of organo mineral complexes (Dwivedi *et al*., 2016) [2]. The maximum soil available phosphorus (kg $ha^{-1}$) at 0-15 and 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*], which was 27.80 and 26.18 and minimum was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 20.00 and 18.55. Similar results have also been recorded by Kumar *et al.* (2011) and Nagar *et al.* (2015) [8]. The maximum soil available potassium (kg $ha^{-1}$) at 0-15 and 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 151.52 and 145.05 and minimum was recorded in $T_1$ [@0% NPKS +@0% *Azotobacter*], which was 142.67 and 135.92. This might be due to adequate supply of N and P2O5 through chemical fertilizers and seed inoculation with *Azotobacter* + PSB which enhanced cell division and cell enlargement which converted more solar energy into chemical energy there by faster growth in term of increase in plant height. Such findings have been also reported by Kumar *et al.* (2014) [6], Nagar *et al.* (2015) [8] and Narinder and Ashwani (2018) [9]. The maximum soil Available Sulphur (mg $kg^{-1}$) at 0-15 and 15-30 cm soil depth was recorded in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 15.03 and 14.66 and minimum was recorded in $T_1$[@0% NPKS +@0% *Azotobacter*], which was 5.53 and 5.16. Similarly, Shilpa and Dongale (2011) [12] reported significant increase in available nutrients (NPK) with the application of organic and inorganic source of nutrients. Application of NPK and S along with *Azotobacter* had positive influence on available S in soil at harvest content over control.

**Table 2:** Chemical properties of soil sample after harvesting of mustard

| Treatments combination | | % Organic Carbon | | Available N (kg $ha^{-1}$) | | Available P (kg $ha^{-1}$) | | Available K (kg $ha^{-1}$) | | Available S (mg $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-15 Cm | 15-30 cm | 0-15 cm | 15-30 Cm | 0-15 cm | 15-30 Cm | 0-15 Cm | 15-30 cm | 0-15 cm | 15-30 cm |
| $T_1$ | [@0% NPKS +@0% *Azotobacter*] | 0.70 | 0.66 | 218.86 | 214.56 | 20 | 18.55 | 142.67 | 135.92 | 5.53 | 5.16 |
| $T_2$ | [@0% NPKS +@50% *Azotobacter*] | 0.71 | 0.67 | 231.6 | 227.3 | 21.93 | 20.48 | 145.5 | 138.76 | 9.73 | 9.36 |
| $T_3$ | [@0% NPKS +@100% *Azotobacter*] | 0.73 | 0.69 | 238.82 | 234.48 | 24.15 | 22.7 | 149.35 | 142.61 | 10.33 | 9.96 |
| $T_4$ | [@50% NPKS +@0% *Azotobacter*] | 0.72 | 0.68 | 233.85 | 229.55 | 21.04 | 19.59 | 143.5 | 136.75 | 11.03 | 10.66 |
| $T_5$ | [@50% NPKS +@50% *Azotobacter*] | 0.74 | 0.7 | 251.56 | 247.26 | 22.96 | 21.51 | 146.63 | 139.89 | 11.03 | 10.66 |
| $T_6$ | [@50% NPKS +@100% *Azotobacter*] | 0.76 | 0.71 | 263.73 | 259.43 | 25.13 | 23.68 | 150.4 | 143.66 | 13.53 | 13.16 |
| $T_7$ | [@100% NPKS +@0% *Azotobacter*] | 0.75 | 0.69 | 259.96 | 255.6 | 22.9 | 21.45 | 144.31 | 137.57 | 13.53 | 13.16 |
| $T_8$ | [@100% NPKS +@50% *Azotobacter*] | 0.77 | 0.71 | 275.66 | 271.36 | 26.02 | 24.57 | 147.52 | 141.12 | 14.73 | 14.36 |
| $T_9$ | [@100% NPKS +@100% *Azotobacter*] | 0.78 | 0.72 | 288.15 | 283.49 | 27.8 | 26.18 | 151.52 | 145.05 | 15.03 | 14.66 |
| F- test | | S | S | S | S | S | S | S | S | S | S |
| S. Ed. (±) | | 0.31 | 0.308 | 6.413 | 5.969 | 1.591 | 1.439 | 0.886 | 0.78 | 0.828 | 1.858 |
| C. D. (P = 0.05) | | 0.65 | 0.646 | 13.468 | 12.536 | 3.34 | 3.023 | 1.861 | 1.638 | 1.739 | 3.902 |

**Growth and Yield Parameters of Mustard**

The result of the maximum plant height at 90 DAS was also found to be significantly in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 169.67 cm followed by $T_8$ [@100% NPKS +@50% *Azotobacter*], followed by $T_7$ [@100% NPKS +@0% *Azotobacter*] and the minimum plant height (103.44 cm) was found in $T_1$ [@0% NPKS +@0% *Azotobacter*].

The result of the maximum number of leaves per plant at 90 DAS was also found to be significantly in $T_9$ [@100% NPKS +@100% *Azotobacter*] which was 17.67 followed by $T_8$ [@100% NPKS +@50% *Azotobacter*], followed by $T_7$ [@100% NPKS +@0% *Azotobacter*] and the minimum number of leaves per plant (13.33) was found in $T_1$ [@0% NPKS +@0% *Azotobacter*].

The maximum Number of Siliqua $plant^{-1}$ (158.60 $plant^{-1}$) of mustard was found in $T_9$ [@100% NPKS +@100% *Azotobacter*], followed by $T_8$ [@100% NPKS +@50% *Azotobacter*], followed by $T_7$ [@100% NPK +@0% *Azotobacter* +@0% Sulphur] and the minimum Number of Siliqua $plant^{-1}$ (87.00 $plant^{-1}$) was found in $T_1$ [@0% NPKS +@0% *Azotobacter*].

The maximum Yield (q $ha^{-1}$) (22.00 q $ha^{-1}$) of mustard was found in $T_9$ [@100% NPK +@100% *Azotobacter* +@80% Sulphur], followed by $T_8$ [@100% NPK +@50% *Azotobacter* +@40% Sulphur], followed by $T_7$ [@100% NPK +@0% *Azotobacter* +@0% Sulphur] and the minimum Yield (q $ha^{-1}$) (11.60 q $ha^{-1}$) was found in $T_1$ [@0% NPK +@0% *Azotobacter* +@0% Sulphur]. Such findings have been also reported by Rajkhowa *et al*., 2003) [11], Kumar *et al.* (2014) [6], Nagar *et al.* (2015) [8] and Narinder and Ashwani (2018) [9].

**Table 3:** Effect of different levels of NPK, Sulphur and *Azotobacter* on growth and Yield of Mustard

| | Treatment combination | Plant height (cm) | Number of leaves plant$^{-1}$ | No. of Siliqua plant$^{-1}$ | Yield (qha$^{-1}$) |
|---|---|---|---|---|---|
| $T_1$ | [@0% NPKS +@0% *Azotobacter*] | 103.44 | 13.33 | 87.00 | 11.60 |
| $T_2$ | [@0% NPKS +@50% *Azotobacter*] | 117.44 | 14.22 | 150.60 | 13.30 |
| $T_3$ | [@0% NPKS +@100% *Azotobacter*] | 119.00 | 15.11 | 131.00 | 15.50 |
| $T_4$ | [@50% NPKS +@0% *Azotobacter*] | 139.44 | 15.67 | 134.00 | 18.60 |
| $T_5$ | [@50% NPKS +@50% *Azotobacter*] | 151.33 | 15.89 | 134.50 | 19.80 |
| $T_6$ | [@50% NPKS +@100% *Azotobacter*] | 156.78 | 16.11 | 143.40 | 20.80 |
| $T_7$ | [@100% NPKS +@0% *Azotobacter*] | 162.22 | 16.78 | 145.60 | 20.00 |
| $T_8$ | [@100% NPKS +@50% *Azotobacter*] | 166.22 | 17.11 | 157.15 | 21.20 |
| $T_9$ | [@100% NPKS +@100% *Azotobacter*] | 169.67 | 17.67 | 158.60 | 22.00 |
| | C.D. at 5% | S | S | S | S |
| | S.Em. (±) | 7.109 | 1.028 | 27.362 | 1.64 |
| | F-Test | 14.929 | 2.179 | 58.007 | 3.45 |

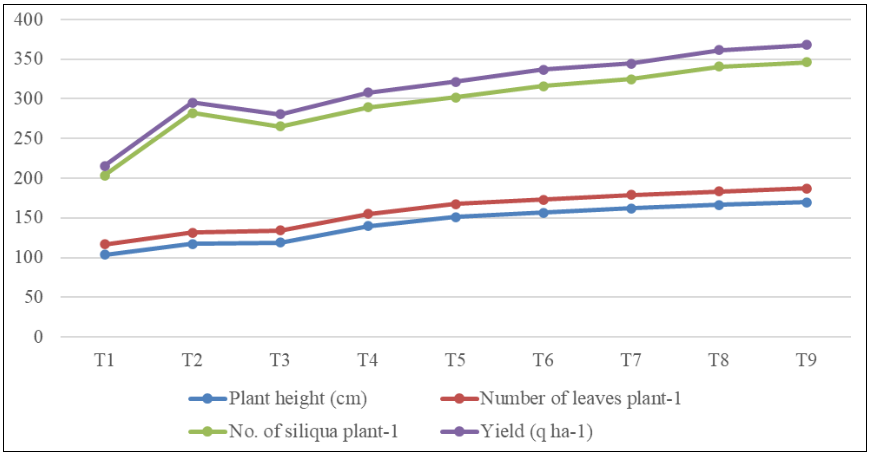


**Fig 1:** Effect of different levels of NPK, Sulphur and *Azotobacter* on growth and Yield of Mustard

## Conclusion

Based on the results, it was found that $T_9$ [@100% NPKS +@100% *Azotobacter*] was the most productive, improved soil health, and was also economically viable. The findings of the experiment showed that the addition of NPKS and *Azotobacter* in treatment $T_9$ improved the soil physicochemical properties the most, as it decreased pH, bulk density, and particle density, while increasing pore space, water holding capacity, EC, organic carbon, available nitrogen, phosphorus, potassium and sulphur.

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