## *Original Research Article*

# Impact assessment of Titanium dioxide nanoparticles ($TiO_2$-NPs) on physico-chemical properties of soil after harvesting of cauliflower (*Brassica oleracea* var. *botrytis*) at Prayagraj District of Eastern Uttar Pradesh


**ABSTRACT**:

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most important winter vegetables among the Cole crops which belongs to the genus *Brassica* of the family Brassicaceae. The current research entitled, Assessment of physical parameters of soil in cauliflower by the application of Titanium-dioxide ($TiO_2$-nanoparticles) in Prayagaraj was conducted during 2022 on the Crop Research Farm of the Department of Soil Science and Agricultural Chemistry, Prayagraj (U.P). There were seven different treatments combinations included in the study comprising treatment $T_1$ as control and treatment $T_2$ to $T_7$ contains 100% RDF through chemical fertilizers along with $TiO_2$ application as seed treatment and foliar spray with concentration of 500, 1000 and 1500 ppm that were replicated three times in Randomized Block Design. The results demonstrated that available N,P & K were significantly affected and physical parameters of soil were non-significantly affected by application of $TiO_2$ nanoparticles applied as seed treatment or foliar spray.



**Keywords**: cauliflower, titanium dioxide, seed treatment, foliar spray, nanoparticles.


## 1. INTRODUCTION:

The soil is a natural habitat for plant growth and it gives plants nutrients. Some soils are productive and sustain luxuriant plant growth with very little human effort, whereas others may be unproductive and support absolutely no beneficial plant life despite all human effort. For soil to be productive, it must meet the following criteria: (i) be easily tillable and fertile; (ii) have all necessary nutrients in quantities that are readily available to plants; and (iii) be physically sound enough to sustain plants and have the ideal moisture and air content for healthy root development. Throughout the plant's existence, the soil must continuously provide these necessities.

Vegetables are essential for human nourishment. These foods are an essential group because they offer the body with vitamins, minerals, protein, carbs, and fiber in addition to their nutritional worth and therapeutic properties. One of the most significant winter vegetables among the many vegetables is cauliflower (*Brassica oleracea* var. *botrytis* L.), which is a member of the genus *Brassica* and family Brassicaceae. Cauliflower may be grown in a variety of soil types, including clay and loam, but the most ideal conditions are reasonably deep loam soil, adequate fertility, and a decent growing environment. Because plants in light soil are more susceptible to drought, water stress has a negative impact on the formation of curds. Soils having a high moisture-holding capacity are preferable for late season/summer. Light soils are necessary for early crops, whereas loamy and clay loam soils are better suited for midseason and late maturing varieties.

As cauliflower is mainly a crop that can withstand low temperatures, it does best in cool, humid climates. The fifth-largest vegetable crop in India is cauliflower, which is largely cultivated in the winter. India produces 5873.3 thousand MT/ha of cauliflower over an area of 433.9 thousand ha, with a productivity rate of 19.8 MT/ha. Fertilizers have a critical function, as seen by the sharp rise in vegetable output and the rise in fertilizer use. West Bengal produced the most cauliflower in 2014, with 73.6 thousand hectares and 1879.0 thousand MT/ha, respectively (National Horticulture Board, 2014).

The experimental side of nanotechnology is gradually giving way to applications in real world settings. The development of so-called "smart fertiliser" as new facilities to improve nutrient use efficiency and lower costs of environmental protection has been made feasible by nanotechnology. These materials can be used as fertilizer transporters or controlled-release vectors. Active food ingredients at the nanoscale (1–100 nm) are the focus of nano fertilizers. These engineered nanoparticles (ENPs) can enter the cells and leaves of plants and can also carry chemicals and DNA into the cells of plants.

In comparison to commonly used pesticides and their formulations, the advantages of nanomaterial-based formulations include improved efficacy due to higher surface area to volume ratio, which provides a better opportunity for interaction, higher solubility, induction of systemic activity due to smaller particle size and higher mobility, and lower toxicity due to the elimination of organic solvents. Nanotechnology creates novel materials that have the potential to overcome many of the drawbacks of traditional conventional materials. It is also predicted to soon become a major economic force with a great potential for attaining sustainable agriculture, particularly in underdeveloped nations. In the field of agriculture, the use of nanomaterial is comparatively new and needs further exploration. Moreover, the emphasis is given to the recent developments in plant science that focuses on agricultural practices, plant growth and yield.

The reason $TiO_2$ NPs were chosen is that they are among the most frequently discussed types in the literature that discusses employing NPs in agriculture. Certain applications include nano fertilizers and nano pesticides to track goods and nutrient levels to boost productivity without decontaminating soils and waters and protection against pests and diseases are of major interest to the agricultural industry. The ingredient Titanium-dioxide ($TiO_2$), one of the most often used in the agricultural and energy sectors, is thought to be advantageous for plant growth and development.

There is some study that primarily focuses on the benefits of nanoparticles for agriculture. The improvement of some key element concentrations in plant tissues, an increase in yield, and an increase in the chlorophyll content of paprika are three of Titanium's most significant effects on plants (*Capsicum annuum* L.). Nano $TiO_2$ application boosted soybean germination, growth, and nitrate reductase activity. Additionally, it has been observed that $TiO_2$ nanoparticles enhance spinach (*Spinacia oleracea*) seed germination and plant growth of spinach. The application of nanoparticles as fertilizer holds considerable promise for improving crop growth and reducing environmental risks. Manufactured nanoparticles may be able to store nutrients on their surfaces for use by organisms as a source of nutrients.

Even, when applied as foliar spray also improved crop production of Cluster bean (*Cyamopsis tetragonoloba* L.). Plants may quickly absorb nano-formulated fertilizers, and they may have a prolonged effective duration of nutrient delivery in the soil or on the plant.

## 2. MATERIALS AND METHODS:

The experiment was carried out at Crop Research Farm, Department of Soil Science and Agricultural Chemistry, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj (UP). The different amounts of Titanium-dioxide ($TiO_2$) were given as a foliar spray and a seed treatment (500, 1000, 1500 ppm). There were three replications and 7 treatment combinations, with treatment $T_1$ serving as the control. Treatments $T_2$-$T_7$ comprised of 100% RDF (chemical fertilizers) along with seed treatment and foliar spray of 500, 1000 and 1500 ppm $TiO_2$ nanoparticles for cauliflower.

**TABLE 1: Methods for the determination of different physical properties of soil.**

| Particular | Method employed | Reference(s) |
| --- | --- | --- |
| Bulk density | Graduated measuring cylinder method. | Muthuaval *et al*., 1992. |
| Particle density | | |
| Water holding capacity | | |
| Available Nitrogen (kg/ha) | Alkaline potassium permanganate method | Subbiah and Asija, 1956 |
| Available Phosphorus (kg/ha) | Calorimetric method | Olsen *et al*., 1954 |
| Available Potassium (kg/ha) | Flame photometric method | Toth and Prince, 1949 |

## 3. RESULTS AND DISCUSSION:

The data given in Table 2, clearly revealed that bulk density of soil is influenced by various treatments. The application of inorganic and organic source of nutrients along with $TiO_2$ nanoparticles had non-significant effect on bulk density of soil. The range of values of bulk density varies from 1.14 to 1.22 Mg $m^{-3}$. Among various treatments the maximum bulk density (1.22 Mg $m^{-3}$) was recorded in treatment $T_4$ and $T_3$ followed by treatment $T_2$ and $T_4$. The minimum bulk density (1.14 Mg $m^{-3}$) was noted under treatment $T_5$. A scrutiny of data presented in Table 3 revealed that application of nanoparticles with chemical fertilizers had non-significant effect on particle density of soil. The range of particle density varies from 2.43 to 2.62 Mg $m^{-3}$. However, the maximum particle density (2.62 Mg $m^{-3}$) was recorded under treatment $T_2$ comprising 100% RDF (chemical fertilizers) + 500 ppm $TiO_2$ (foliar spray) in cauliflower and the minimum particle density (2.43 Mg $m^{-3}$) was noted under treatment $T_6$ [100% RDF (chemical fertilizers) + 1000 ppm $TiO_2$ (seed treatment)] and treatment $T_7$ (100% RDF + 1500 ppm $TiO_2$ seed treatment). The data regarding the water holding capacity in soil as influenced by different treatments is given in Table 4, the application of various treatments had non-significant effect on water holding capacity of soil in cauliflower. The range of water holding capacity varies from 46.20 to 46.81 %. However, the maximum water holding capacity (46.81 %) was recorded under treatment $T_3$ i.e., 100% RDF (chemical fertilizers) +1000 ppm $TiO_2$ as foliar spray. The minimum (46.20 %) water holding capacity was noted under treatment $T_6$ with 100% RDF (chemical fertilizers) + 1000 ppm $TiO_2$ (seed treatment). Similar findings are in accordance with the studies conducted by Badhulkar *et al*. (2000)17, Selvi *et al*. (2004)18 and Bajpai *et al*. (2006)19, concluded that long term research and experimentation may modify some of the physicochemical characteristics of soil.

A scrutiny of data presented in Table 5 revealed that there was significant increment in available soil nitrogen due to application of nanoparticles along with chemical fertilizers. The significant higher (287.74 kg $ha^{-1}$) value of available nitrogen was recorded under treatment $T_4$ comprising 100% RDF (chemical fertilizers) + 1500 ppm $TiO_2$ (foliar spray) in cauliflower followed by treatment $T_1$. However, the minimum available nitrogen (239.49 kg $ha^{-1}$) was noted under treatment $T_6$ [100% RDF (chemical fertilizers) + 1000 ppm $TiO_2$ (seed treatment).

The data regarding the available phosphorus in soil as influenced by different treatments is given in Table 6. On statistical analysis it was noted that significantly higher (22.60 kg $ha^{-1}$) phosphorus content of soil was revealed under treatment $T_4$ i.e., 100% RDF (chemical fertilizers) +1500 ppm $TiO_2$ as foliar spray in cauliflower. The minimum (16.06 kg $ha^{-1}$) amount of available phosphorous was noted under treatment $T_6$ with 100% RDF (chemical fertilizers) + 1000 ppm $TiO_2$ (seed treatment) as given in Table 6.

A significant difference was revealed on analysing the data regarding available potassium content in soil as given in Table 7. Significantly higher (202.11 kg $ha^{-1}$) value of available potassium was recorded in treatment $T_4$ in cauliflower. The minimum (192.95 kg $ha^{-1}$) available potassium was recorded under treatment $T_6$ with 100% RDF (chemical fertilizers) + 1000 ppm $TiO_2$ (seed treatment) in cauliflower.

Nitrogen, Phosphorus and Potassium availability in treatments with foliar application and seed treatment with $TiO_2$ nanoparticles may have been further reduced due to improved nutrient absorption from the soil brought on by application of different treatments. Similar research was also reported by Osterhius (1998), who came to the conclusion that nutrient supplementation through foliar and seed treatment might improve soil nutrient absorption, boost crop productivity, and decrease the quantity of fertilizer used on the soil (Ahmad, 1988).

**Table 2: Effect on bulk density of soil in cauliflower by the application of nanoparticles ($TiO_2$)**

| Treatments | | Bulk density (Mg $m^{-3}$) |
|---|---|---|
| **T1** | Control (100% RDF) | 1.19 |
| **T2** | 100% RDF + 500 ppm $TiO_2$ Foliar Spray | 1.20 |
| **T3** | 100% RDF + 1000 ppm $TiO_2$ Foliar Spray | 1.22 |
| **T4** | 100% RDF + 1500 ppm $TiO_2$ Foliar Spray | 1.22 |
| **T5** | 100% RDF + 500 ppm $TiO_2$ Seed Treatment | 1.14 |
| **T6** | 100% RDF + 1000 ppm $TiO_2$ Seed Treatment | 1.16 |
| **T7** | 100% RDF + 1500 ppm $TiO_2$ Seed Treatment | 1.14 |
| **F-Test** | | NS |
| **S. Em. (±)** | | - |
| **CD (at 5 %)** | | - |

**Table 3. Effect on particle density of soil in cauliflower by the application of nanoparticles ($TiO_2$)**

| Treatments | | Particle density (Mg $m^{-3}$) |
|---|---|---|
| **T1** | Control (100% RDF) | 2.55 |
| **T2** | 100% RDF + 500 ppm $TiO_2$ Foliar Spray | 2.62 |
| **T3** | 100% RDF + 1000 ppm $TiO_2$ Foliar Spray | 2.56 |
| **T4** | 100% RDF + 1500 ppm $TiO_2$ Foliar Spray | 2.51 |
| **T5** | 100% RDF + 500 ppm $TiO_2$ Seed Treatment | 2.58 |

| | | |
|---|---|---|
| T6 | 100% RDF + 1000 ppm $TiO_2$ Seed Treatment | 2.43 |
| T7 | 100% RDF + 1500 ppm $TiO_2$ Seed Treatment | 2.55 |
| F-Test | | NS |
| S. Em. (±) | | - |
| CD (at 5 %) | | - |

**Table 4. Effect on water holding capacity of soil in cauliflower by the application of nanoparticles ($TiO_2$).**

| Treatments | | Water holding capacity (%) |
|---|---|---|
| T1 | Control (100% RDF) | 46.49 |
| T2 | 100% RDF + 500 ppm $TiO_2$ Foliar Spray | 46.67 |
| T3 | 100% RDF + 1000 ppm $TiO_2$ Foliar Spray | 46.81 |
| T4 | 100% RDF + 1500 ppm $TiO_2$ Foliar Spray | 46.26 |
| T5 | 100% RDF + 500 ppm $TiO_2$ Seed Treatment | 46.53 |
| T6 | 100% RDF + 1000 ppm $TiO_2$ Seed Treatment | 46.20 |
| T7 | 100% RDF + 1500 ppm $TiO_2$ Seed Treatment | 46.80 |
| F-Test | | NS |
| S. Em. (±) | | - |
| CD (at 5 %) | | - |

**Table 5. Effect of $TiO_2$ (nano-particles) and chemical fertilizers on available Nitrogen (kg $ha^{-1}$) of soil after crop harvest.**

| Treatments | | Available N (Kg $ha^{-1}$) |
|---|---|---|
| T1 | Control (100% RDF) | 278.69 |
| T2 | 100% RDF + 500 ppm $TiO_2$ Foliar Spray | 265.25 |
| T3 | 100% RDF + 1000 ppm $TiO_2$ Foliar Spray | 258.84 |
| T4 | 100% RDF + 1500 ppm $TiO_2$ Foliar Spray | 287.74 |
| T5 | 100% RDF + 500 ppm $TiO_2$ Seed Treatment | 241.94 |
| T6 | 100% RDF + 1000 ppm $TiO_2$ Seed Treatment | 239.49 |

| | | |
|---|---|---|
| **T7** | 100% RDF + 1500 ppm $TiO_2$ Seed Treatment | 247.64 |
| **F-Test** | | S |
| **S. Em. (±)** | | 0.35 |
| **CD** ( at 5 %) | | 1.06 |

**Table 6. Effect of $TiO_2$ (nano-particles) and chemical fertilizers on available Phosphorus (kg $ha^{-1}$) of soil after crop harvest.**

| **Treatments** | | **Available P (Kg $ha^{-1}$)** |
|---|---|---|
| **T1** | Control (100% RDF) | 21.60 |
| **T2** | 100% RDF + 500 ppm $TiO_2$ Foliar Spray | 20.29 |
| **T3** | 100% RDF + 1000 ppm $TiO_2$ Foliar Spray | 18.48 |
| **T4** | 100% RDF + 1500 ppm $TiO_2$ Foliar Spray | 22.60 |
| **T5** | 100% RDF + 500 ppm $TiO_2$ Seed Treatment | 17.01 |
| **T6** | 100% RDF + 1000 ppm $TiO_2$ Seed Treatment | 16.06 |
| **T7** | 100% RDF + 1500 ppm $TiO_2$ Seed Treatment | 17.68 |
| **F-Test** | | S |
| **S. Em. (±)** | | 0.26 |
| **CD** ( at 5 %) | | 0.8 |

**Table 7. Effect of $TiO_2$ (nano-particles) and chemical fertilizers on available Potassium (kg $ha^{-1}$) of soil after crop harvest.**

| **Treatments** | | **Available K (Kg $ha^{-1}$)** |
|---|---|---|
| **T1** | Control (100% RDF) | 199.37 |
| **T2** | 100% RDF + 500 ppm $TiO_2$ Foliar Spray | 196.87 |
| **T3** | 100% RDF + 1000 ppm $TiO_2$ Foliar Spray | 197.67 |
| **T4** | 100% RDF + 1500 ppm $TiO_2$ Foliar Spray | 202.11 |
| **T5** | 100% RDF + 500 ppm $TiO_2$ Seed Treatment | 196.59 |
| **T6** | 100% RDF + 1000 ppm $TiO_2$ Seed Treatment | 192.95 |

| | | |
|---|---|---|
| T7 | 100% RDF + 1500 ppm $TiO_2$ Seed Treatment | 198.63 |
| **F-Test** | | S |
| **S. Em. (±)** | | 0.51 |
| **$CD_{(\text{at } 5\ \%)}$** | | 1.58 |

## 4. CONCLUSIONS

The study revealed that seed treatment with nanoparticles ($TiO_2$) and foliar spray in combination with chemical fertilizers had a significant effect on available NPK (kg $ha^{-1}$) of soil after crop harvest and a non-significant effect on bulk density (Mg $m^{-3}$), particle density (Mg $m^{-3}$) and water holding capacity of soil. However, it may affect these soil physical properties after long term experimentations and trials.

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