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Effect of Nano Urea in Combination with *Azotobacter* on Growth and Yield of Strawberry (*Fragaria* x *ananassa* Dutch.) cv. Winter Dawn in Trans-Gangetic Region

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Abstract

A study was performed to evaluate the effect of nano urea along with *Azotobacter* on growth and yield of strawberry during 2022-23, under protected conditions. Plant growth characters were analysed for the various doses and combinations of nano urea and with the combination of *Azotobacter*. The findings presented herein clearly demonstrate the ability of strawberry plants to discern and harness the urea supplied through nanoparticles via foliar spray as compared to the conventional soil application method. Furthermore, all quantitative parameters assessed in strawberries nourished with nanoparticles exhibited a flawless correlation with those observed in plants cultivated under conventional conditions, despite the limited nitrogen dosage associated with nanoparticle supplementation. As a result, these outcomes furnish compelling substantiation of the effectiveness of urea nanoparticles as a nitrogen source, laying the foundation for the formulation of alternative nitrogen fertilization strategies. This approach aims to optimize the dosage ratio and holds promise within the framework of fostering a more ecologically sound and contemporary approach to strawberry cultivation.

Keywords

Nano urea, *Azotobacter*, Growth, Yield, Strawberry

Introduction

Strawberry is a widely cultivated cash crop appreciated by many people in various forms, including fresh fruits and extracts. Botanically known as *Fragaria* x *ananassa* Duch, it belongs to the Rosaceae family and has an octoploid chromosome number of 56 (2n = 8x). The fruit is highly favoured by consumers primarily due to their taste [1, 2]. This fruit possesses a delightful taste and flavor and is highly nutritious, serving as an excellent source of vitamins, fiber, potassium, and sugars [3]. In addition to its dessert-like qualities, strawberries are rich in antioxidants [4], offering numerous health benefits. The flavor profile of the fruit is comprised of three key components: sugars, acids, and aromatic compounds. Among the volatile compounds responsible for the fruit's flavor, ethyl esters such as ethyl hexanoate and ethyl butanoate play a major role. Ellagic acid, an anti-mutagenic and anti-carcinogenic plant phenol, can be found in the leaf tissues and red achenes of strawberry fruit [5].

Over time, strawberry cultivation has seen advancements in understanding plant physiology, cultivation systems, nutritional requirements, and other aspects of crop production, resulting in improved practices [6]. With advancements in technology and the availability of various strawberry varieties, these fruits can now be found in the market year-round. Strawberry responds well to nutrient management and for successful cultivation of the crop, an adequate supply of nutrients is required. However, still conventional fertilizers are used for the commercial production of the strawberry. In this context, use of nano fertilizers holds

promise as evident from experimentation on other fruit crops. Nano fertilizers have advantage of better absorption resulting in optimized use of resources with better production as reported for other fruit crops. Urea being the most required fertilizer for crop production is used widely for increasing the vegetative growth as well as production potential of the crops. With the availability of nano form of urea, application of nitrogen can be optimized for quality growth and enhanced production. The utilization of bio-fertilizers in conjunction with organic fertilizers has been found to enhance both the growth and quality of plant production [7, 8]. *Azotobacter* stimulates the production of auxins, cytokinins, and other compounds that facilitate growth and development [9]. This combined approach has also been observed to have positive effects on soil health, as indicated by increased fertilizer utilization efficiency, nutrient uptake, and the growth and yield of strawberry plants [10-12].

In addition to that, conjunctive use of bio-fertilizers helps to overcome the nutrient availability barriers and improves the soil health for better plant growth and productivity [13]. Given that strawberry plants possess a shallow root system, it is imperative to implement effective and balanced nutrient management throughout their growth cycle. Recognizing the critical role of soil fertility in ensuring sustainable crop production and optimizing strawberry quality, the current study proposes an experiment involving the combined application of fertilizers and bio-fertilizers. The primary aim of this investigation is to assess how different nitrogen (N) fertilizer rates, along with bio fertilizers, impact the growth, yield, and quality of strawberry plants. This research endeavour seeks to contribute to a profound understanding of optimal fertilization strategies that enhance strawberry production while simultaneously upholding soil health and overall sustainability.

Material and Methods

The present study was conducted at the experimental field of Horticulture, Lovely Professional University, Punjab, India, during the year 2022-23. Runner-grown seedlings of the Strawberry cv. Winter Dawn were obtained from Shimla. All intercultural operations and fertility management practices were carried out according to commercial recommendations. The experiment was laid out in a randomized block design with three replications. The unit plot size measured 24 m x 0.6 m consisting of 10 plants spaced at 45 cm x 30 cm. Data regarding vegetative growth and fruit yield were collected from every individual plant within each replicated plot.

Plant growth parameters recorded at 30 days of intervals till harvest included plant height, plant spread (East to west (EW) and north to south (NS)), chlorophyll index, number of flowers, number of leaves, yield, and total number of fruits. Plant height and plant spread was recorded using a graduated scale. Number of leaves and number of flowers were counted manually on tagged plants. Leaf chlorophyll index was assessed using a SPAD-502 chlorophyll meter by taking two trifoliate leaves per plant. Total number of fruits was counted individually for each plant and yield was calculated by multiplying the number of fruits and average weight of the fruit.

Statistical analysis

The data generated was statistically analysed using SPSS v. 23 (SPSS Inc.) software to arrive at the homogenous subsets. Variables having non-significant differences are superscripted with same alphabets.

Results

Plant height significantly varied among different treatments (Table 1 and figure 1). Overall, there was a gradual increase in the plant height at all the observation intervals. At 120 days after planting (DAP), maximum plant height (12.44 cm) was observed under the T_9 (25% RDF + N_2 + *Azotobacter*).

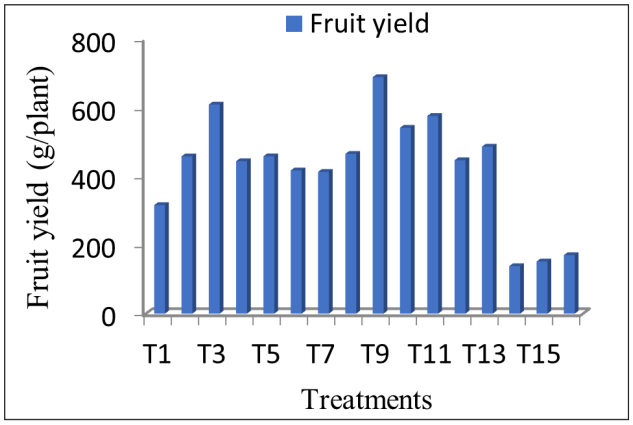

Figure 1: Effect of nano urea in combination with *Azotobacter* on fruit yield of strawberry cv. Winter Dawn.

Table 1: Effect of nano urea in combination with *Azotobacter* on plant height of strawberry cv. Winter Dawn.

Treatment	30th Day	60th Day	90th Day	120th Day
T_1	3.13^{a}	4.16^{b}	6.18^{a}	9.99^{a}
T_2	3.14^{a}	4.51^{e}	6.48^{b}	10.30^{bc}
T_3	3.21^{a}	5.04^{j}	7.60^{e}	11.91^{de}
T_4	3.22^{a}	4.9^{g}	7.07^{cd}	11.16^{bcd}
T_5	3.19^{a}	4.94^{h}	7.27^{d}	11.08^{bcd}
T_6	3.21^{a}	4.08^{a}	7.61^{e}	10.77^{bcd}
T_7	3.20^{a}	4.68^{f}	6.59^{b}	11.08^{bcd}
T_8	3.25^{a}	5.41^{l}	7.50^{e}	11.64^{de}
T_9	3.15^{a}	5.6^{m}	7.83^{f}	12.44^{e}
T_{10}	3.20^{a}	5.2^{k}	7.50^{e}	11.83^{de}
T_{11}	3.20^{a}	5^{i}	7.20^{d}	11.79^{de}
T_{12}	3.28^{a}	4.9^{g}	6.95^{c}	11.28^{bcde}
T_{13}	3.22^{a}	4.7^{f}	6.87^{c}	11.39^{cde}
T_{14}	3.26^{a}	4.3^{d}	6.50^{b}	10.08^{b}
T_{15}	3.20^{a}	4.2^{c}	6.37^{ab}	10.12^{ab}
T_{16}	3.30^{a}	4.2^{c}	6.22^{a}	10.06^{ab}

Other treatments where nitrogen was applied in nano form also showed incremental progression in plant height. However, minimum plant height was recorded in the treatment where urea was applied as a source of nitrogen. Better absorption of nano nitrogen particles might have resulted in enhanced growth as against urea which is prone to leaching. This might have resulted in superior performance of all the treatments where nano nitrogen was applied. The horizontal expansion of the plants from EW direction showed considerable variation across the different treatments, as indicated in table 2. A consistent increase in plant spread in the EW direction was observed every 30 days. Among these, the greatest expansion was observed at 120 DAP in treatment T_9, where it reached 22.00 cm. This was followed by T_3 with a spread of 21.23 cm and T_8 with 20.37 cm, in comparison to the control group (T_1) which had a plant spread of 18.30 cm. Notably, treatment T_9 stood out significantly among all the applied treatments for the winter dawn strawberry cultivar. Plants spread (NS) also showed significant differences among the treatments (Table 3). Maximum increase in plant spread (NS) was recorded at 12 DAP under T_9 (22.4 cm) followed by T_3 and T_8 with measurements of 21.1 cm and 21.0 cm respectively. These values were significantly different from T_1 (control), which was 17.4 cm on the 120th DAP.

The chlorophyll index illustrated the variation among treatments, shown in table 4. Continuous increase chlorophyll was recorded after every 30 days of intervals. Moreover, the maximum expansion was observed at 120th DAP, which is depicted by T_9, where it reached up to 55.97 followed by T_3 and T having the value 55.01 and 54.67 respectively. The obtained values were found significant against T_1 (control) which was recorded 17.4 cm on 120th DAP.

Table 2: Effect of nano urea in combination with *Azotobacter* on plant spread (EW) of strawberry cv. Winter Dawn.

Treatment	30th Day	60th Day	90th Day	120th Day
T_1	12.27^{a}	14.13^{d}	16.27^{d}	18.30^{c}
T_2	11.93^{a}	15.60^{h}	17.53^{f}	19.77^{g}
T_3	12.40^{a}	16.80^{k}	19.00^{i}	21.23^{j}
T_4	12.00^{a}	15.17^{g}	17.40^{f}	19.23^{f}
T_5	11.90^{a}	15.60^{h}	17.63^{fg}	19.67^{a}
T_6	12.03^{a}	14.53^{e}	16.60^{e}	18.57^{cd}
T_7	12.23^{a}	14.87^{f}	16.57^{de}	18.73^{de}
T_8	11.90^{a}	16.10^{j}	18.13^{h}	20.37^{i}
T_9	12.07^{a}	17.23^{l}	19.40^{j}	22.00^{k}
T_{10}	12.33^{a}	15.50^{h}	17.47^{f}	19.50^{fg}
T_{11}	12.00^{a}	15.83^{i}	17.87^{gh}	20.07^{h}
T_{12}	11.93^{a}	14.80^{f}	16.83^{e}	18.87^{e}
T_{13}	12.07^{a}	15.43^{h}	17.47^{f}	19.50^{a}
T_{14}	12.07^{a}	12.13^{a}	14.17^{a}	16.07^{a}
T_{15}	11.90^{a}	12.60^{b}	14.53^{b}	16.15^{a}
T_{16}	12.23^{a}	13.50^{c}	14.97^{c}	17.20^{b}

Table 3: Effect of nano urea in combination with *Azotobacter* on plant spread (NS) of strawberry cv. Winter Dawn.

Treatment	30th Day	60th Day	90th Day	120th Day
T_1	11.30^{i}	13.47^{c}	15.08^{c}	17.4^{c}
T_2	11.23^{e}	14.70^{defgh}	16.41^{e}	18.9^{f}
T_3	11.26^{f}	15.40^{i}	17.30^{h}	21.1^{h}
T_4	11.21^{d}	14.47^{def}	16.07^{d}	18.0^{d}
T_5	11.19^{c}	14.63^{defgh}	16.50^{e}	18.2^{de}
T_6	11.23^{e}	14.23^{d}	15.57	19.0^{fg}
T_7	10.85^{a}	14.37^{de}	16.07^{d}	18.3^{e}
T_8	11.43^{k}	15.10^{hi}	17.10^{gh}	21.0^{h}
T_9	11.24^{e}	16.10^{j}	18.00^{i}	22.4^{i}
T_{10}	11.28^{gh}	14.93^{fghi}	16.87^{f}	19.0^{fg}
T_{11}	11.39^{j}	15.03^{ghi}	16.97^{fg}	19.2^{g}
T_{12}	10.98^{b}	14.60^{defg}	16.37^{e}	18.0^{d}
T_{13}	11.29^{hi}	14.83^{efgh}	16.53^{e}	19.0^{fg}
T_{14}	11.26^{f}	12.30^{a}	14.73^{a}	16.1^{a}
T_{15}	11.19^{c}	12.53^{ab}	14.90^{ab}	16.2^{a}
T_{16}	11.27^{fg}	12.77^{b}	14.97^{b}	16.8^{b}

Table 4: Effect of nano urea in combination with *Azotobacter* on chlorophyll index of strawberry cv. Winter Dawn.

Treatment	30th Day	60th Day	90th Day	120th Day
T_1	47.56^{a}	48.96^{abc}	50.86^{bcd}	52.60^{b}
T_2	47.77^{a}	49.92^{abcde}	52.72^{def}	54.70^{def}
T_3	47.61^{a}	50.24^{cde}	52.93^{ef}	55.01^{ef}
T_4	47.85^{a}	49.63^{abcd}	51.92^{def}	53.45^{abc}
T_5	47.54^{a}	49.81^{abcde}	51.91^{def}	53.57^{bcde}
T_6	47.69^{a}	49.68^{abcd}	50.87^{bcd}	52.38^{b}
T_7	47.78^{a}	49.77^{abcd}	51.20^{cde}	52.48^{b}
T_8	47.83^{a}	50.63^{de}	52.82^{ef}	54.67^{def}
T_9	47.64^{a}	51.46^{e}	53.37^{f}	55.97^{f}
T_{10}	47.59^{a}	50.87^{de}	52.07^{def}	53.77^{bcde}
T_{11}	47.56^{a}	51.15^{de}	51.92^{def}	54.13^{cde}
T_{12}	47.67^{a}	49.95^{bcde}	51.30^{cde}	52.95^{ab}
T_{13}	47.62^{a}	50.08^{bcde}	51.53^{def}	53.04^{ab}
T_{14}	47.57^{a}	48.28^{a}	49.02^{a}	50.09^{a}
T_{15}	47.54^{a}	48.48^{ab}	49.24^{ab}	50.37^{a}
T_{16}	47.60^{a}	48.63^{abc}	49.57^{abc}	50.63^{a}

The quantification of number of flowers exhibited notable

variation across the complete spectrum of treatments (Table 5). A systematic augmentation in the floral count was meticulously documented at intervals of 30 days. Preeminent floral profusion materialized at the juncture of 120 DAP within treatment regimen T_9, manifesting a conspicuous figure of 17.3 flowers which was significantly superior to that observed in control (13.5). It is noteworthy that treatment T_9 exhibited marked statistical significance when compared against the entirety of administered interventions within the purview of the Winter Dawn strawberry cultivar. Similar results were found in study of Bhatti et al. [14].

During the harvest period, which occurred around 118 DAP, the fruit yield resulting from various treatments in this study was meticulously documented, illustrated in figure 1. Among these treatments, treatment T_9 exhibited the highest fruit yield, recording a substantial amount of 688.75 g. Notably, this yield was significantly superior to the rest of the treatments. Following T_9, treatment T_3 attained a yield of 608.89 g, while T_{11} yielded 574.84 g. The evaluation of fruit yield assumes a central role within the context of this research undertaking, representing a crucial facet of the study's framework. The fruit yield of different treatments in this research study was recorded at the time of harvesting period, 118 DAP approximately. The similar results were lucid from the study of Gaiotti et al. [15].

Notably, treatment T_9 displayed a conspicuous degree of statistical significance when contrasted with the entire array of administered interventions within the scope of the Winter Dawn strawberry cultivar (Table 6). The treatments utilizing nanoscale nitrogen demonstrated a gradual increase in fruit count as depicted in figure 2. In contrast, the lowest fruit count was recorded in the treatment using urea as the nitrogen source. The improved effectiveness of strawberry plants with nano urea fertilization can be attributed to the easy assimilation and enhanced absorption of nitrogen nanoparticles, compared to traditional soil-applied urea that is prone to leaching. This likely led to superior performance across all treatments utilizing nano urea. Similar results were found due to the influence of nano nitrogen in the study Gaiotti et al. [15].

Conclusion

From the findings perceived thorough this research, it can be concluded that for profitable production and resource utilization in strawberry, a dosage of 400 ppm nano urea in the

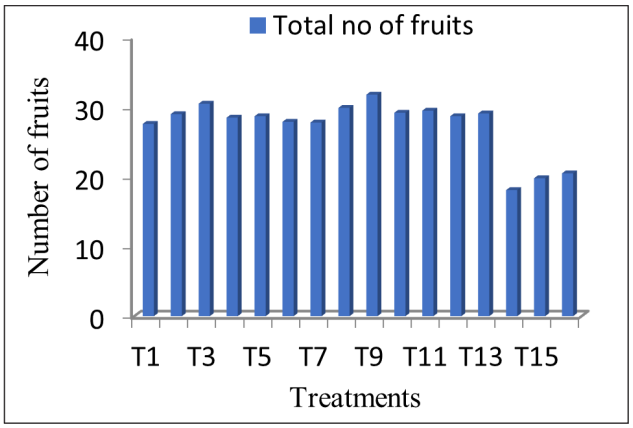

Figure 2: Effect of nano urea in combination with *Azotobacter* on total number of fruits of strawberry cv. Winter Dawn.

Table 5: Effect of nano urea in combination with *Azotobacter* on number of flowers of strawberry cv. Winter Dawn.

Treatment	60th Day	90th Day	120th Day
T_1	0.77^{bcd}	2.40^{c}	1.47^{ef}
T_2	0.97^{efghi}	3.00^{f}	1.77^{f}
T_3	1.13^{j}	3.70^{h}	2.07^{h}
T_4	0.90^{defg}	2.80^{e}	1.37^{cd}
T_5	0.93^{efgh}	2.97^{f}	1.47^{ef}
T_6	0.83^{bcde}	2.63^{d}	1.27^{bc}
T_7	0.87^{cdef}	2.67^{d}	1.37^{cd}
T_8	1.00^{fghij}	3.07^{f}	1.97^{g}
T_9	1.38^{k}	4.20^{j}	2.47^{i}
T_{10}	1.03^{ghij}	3.77^{h}	1.77^{f}
T_{11}	1.10^{ij}	3.90^{i}	1.87^{f}
T_{12}	1.00^{fghij}	3.57^{g}	1.47^{ef}
T_{13}	1.07^{hij}	3.67^{gh}	1.57^{e}
T_{14}	0.60^{a}	2.10^{a}	0.97^{a}
T_{15}	0.70^{ab}	2.20^{ab}	1.17^{b}
T_{16}	0.73^{abc}	2.23^{b}	1.27^{bc}

Table 6: Effect of nano urea in combination with *Azotobacter* on number of leaves of strawberry cv. Winter Dawn.

Treatment	30th Day	60th Day	90th Day	120th Day
T_1	3.7^{a}	5.6^{a}	9.1^{c}	13.5^{c}
T_2	3.6^{a}	6.0^{bcd}	10.6^{hi}	15.0^{f}
T_3	3.5^{a}	6.3^{def}	11.6^{k}	16.5^{h}
T_4	3.2^{a}	6.1^{bcd}	9.7^{e}	14.3^{d}
T_5	3.1^{a}	6.2^{cde}	10.0^{f}	14.6^{e}
T_6	3.4^{a}	6.2^{cde}	9.4^{d}	13.8^{c}
T_7	3.0^{a}	6.1^{cde}	9.5^{d}	14.3^{de}
T_8	3.3^{a}	6.1^{cde}	11.1^{j}	15.7^{g}
T_9	3.6^{a}	6.6^{f}	12.2^{l}	17.3^{i}
T_{10}	3.3^{a}	6.4^{ef}	10.6^{h}	15.0^{f}
T_{11}	3.4^{a}	6.1^{cde}	10.8^{i}	15.8^{g}
T_{12}	3.5^{a}	6.0^{bcd}	10.0^{f}	14.3^{d}
T_{13}	2.7^{a}	6.1^{cde}	10.3^{g}	14.6^{de}
T_{14}	3.3^{a}	5.8^{ab}	8.3^{a}	11.9^{a}
T_{15}	3.2^{a}	5.9^{bc}	8.5^{b}	12.1^{a}
T_{16}	3.3^{a}	6.1^{cde}	8.6^{b}	12.5^{b}

form of foliar application along with *Azotobacter* inoculation can be recommended. Further studies are required on mode of application of nano urea and the residual effect of the same on crop, soil and biotic factors involved.

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Conflict of Interest

The authors declare that there is no conflict of interest among the authors or the institution where the research work was carried out.

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