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EFFECT OF GIBBERELLIC ACID, AZOTOBACTER AND NEEM CAKE ON YIELD OF POTATO (*SOLANUM TUBEROSUM* L.) GROWN IN GWALIOR REGION OF INDIA

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ABSTRACT

The research study was carried out at the Research Field CRC-3, Turari, ITM University, Gwalior (M.P.), India. The experiment was organized using a Randomized Block Design with three replications. Each replication included eleven treatment combinations of Gibberellic acid, Azotobacter and Neem cake, along with varying recommended doses of fertilizers applied to the potato variety Kufri Pukhraj. The findings indicated that the various treatments involving Gibberellic acid, Azotobacter, and Neem cake, along with different fertilizer doses, had a significant impact on the growth, yield, and quality parameters of potatoes at different growth stages. The treatment T_7-75% RDF + 25% FYM + Azotobacter (10g/kg tuber) + GA_3 (100ppm) emerged as the most effective treatment compared to the others, yielding the highest growth, yield and quality parameters for the potatoes. This treatment also resulted in the highest net returns (Rs 265393/ha). The highest benefit-cost ratio (2.53) was observed in treatments T_8-75%RDF + 25% Neem cake + Azotobacter (10g/kg) + GA_3 (100ppm) and T_7 - 75% RDF + 25% FYM + Azotobacter (10g/kg) + GA_3 (100ppm).

Key words : Gibberellic acid, Potato, Azotobacter, Neem cake.

Introduction

The potato (*Solanum tuberosum* L.), commonly referred to as “Aloo” in many parts of the world, is a highly versatile and productive crop belonging to the Solanaceae family, which encompasses 90 genera and 2,800 species. Originating from South America, the potato is often called the “King of Vegetables” due to its remarkable adaptability and significant contribution to food security. The name “potato” is derived from the Incas words “papa” or “batata”.

Introduced to India in the early 17th century from Europe, specifically as the Irish potato, it initially thrived in the northern and southern hills and parts of the central plains. Today, the potato is a crucial crop in India, particularly in high-population regions of Asia, due to its high yield of dry-matter food, well-balanced protein and caloric content per unit area and time.

Most commercial potato cultivars are tetraploid (2n=48), making them genetically robust. The potato is an annual, herbaceous plant with dicotyledonous characteristics, primarily self-pollinating, and typically propagated vegetatively, although it can also be grown from True Potato Seed (TPS). The potato tuber, a modified underground stem formed on a stolon, contains dormant buds (eyes) and scaly leaves (eyebrows). The tuber’s parenchyma tissue stores complex carbohydrates as starch grains, contributing to its nutritional value. The plant’s extended growing period results in the production of an inedible berry resembling a tomato.

Given its significance, optimizing potato cultivation practices is crucial for maximizing yield and quality, especially in regions like Gwalior with unique climatic and soil conditions.

Gibberellins are a group of plant growth regulators known for their role in promoting stem elongation, leaf

expansion, seed germination and flowering. When it comes to potato (*Solanum tuberosum*) growth, the application of Gibberellins can have several notable effects. Tuber Initiation and Development are Gibberellins have been shown to stimulate tuber initiation and development in potatoes (Kumar *et al*., 2012 and Paikra *et al*., 2020).

This research investigates the impact of Gibberellic acid, Azotobacter and Neem cake on the growth and yield of the potato variety Kufri Pukhraj under Gwalior's specific conditions. Utilizing a Randomized Block Design with various treatment combinations, this study aims to identify the most effective agronomic practices to enhance potato growth, yield and quality. The outcomes are anticipated to provide valuable insights into sustainable potato cultivation, benefiting both farmers and the broader agricultural sector (Sarma and Sarkar, 2008; Sillu *et al*., 2012; Singh *et al*., 2003; Pandita *et al*., 1981; Usha *et al*., 2009).

Materials and Methods

Gwalior, located in northern Madhya Pradesh, presents a unique set of environmental conditions for agricultural research. Despite being surrounded by hills in the south, Gwalior's elevation is relatively modest, averaging only a few hundred feet above sea level. Positioned at 26.22°N latitude and 78.18°E longitude, the city stands at an average elevation of 197 meters (646 feet). Gwalior experiences a subtropical climate characterized by extreme temperatures in both summer and winter.

Summers in Gwalior are notably hot and dry, with average temperatures around 30°C, but capable of soaring up to 45°C. The peak summer months of May and June see mean maximum temperatures ranging from 37°C to 46.4°C. Conversely, winters are quite cold, with average temperatures ranging from 8°C to 10°C, and the mercury can dip as low as 2°C during December and January, the coldest months of the year. The region receives mean annual rainfall between 700 and 750 mm, primarily during the monsoon season from mid-June to the end of September.

The research study was designed using a Randomized Block Design with three replications to evaluate the effects of various treatments on the growth and yield of the potato variety Kufri Pukhraj. Each replication included the following eleven treatments:

T_1: 100% RDF

T_2: 75% RDF + 25% FYM

T_3: 75% RDF + 12.5% FYM + 12.5% Neem Cake

T_4: 50% RDF + 25% FYM + 25% Neem Cake

T_5: 75% RDF + 12.5% FYM + 12.5% Neem Cake + Azotobacter (10g/kg tuber)

T_6: 75% RDF + 12.5% FYM + 12.5% Neem Cake + GA_3 (100ppm)

T_7: 75% RDF + 25% FYM + Azotobacter (10g/kg tuber) + GA_3 (100ppm)

T_8: 75% RDF + 25% Neem Cake + Azotobacter (10g/kg tuber) + GA_3 (100ppm)

T_9: 75% RDF + 25% FYM + 25% Neem Cake + GA_3 (100ppm)

T_{10}: 75% RDF + 25% FYM + GA3 (100ppm)

T_{11}: 75% RDF + 25% Neem Cake + Azotobacter (10g/kg tuber)

These treatments incorporated different combinations of Gibberellic acid, Azotobacter, FYM (Farm Yard Manure), Neem Cake and recommended doses of fertilizers to assess their impact on potato growth and yield under the specific climatic conditions of Gwalior. The results of this study aim to provide valuable insights into effective agronomic practices for enhancing potato production in this region.

Observation's recorded

During the experimentation period, data were meticulously recorded across various yield parameters following standard procedures.

Yield parameters

- **Total Number of Tubers per Plant :** Tubers were counted from five randomly selected plants in each plot, with the average number per plant calculated. This process was repeated across all replications manually.
- **Tuber Diameter (cm) :** At harvest, the diameter of fresh tubers from five randomly selected plants per plot was measured using a Vernier Caliper. The average tuber diameter was then calculated in centimetres.
- **Average Tuber Weight (g) :** The weight of tubers from five randomly selected plants was recorded at harvest using a physical balance. The average tuber weight per plant was calculated and expressed in grams.
- **Total Tuber Yield (kg/plot) :** The total yield per plot was recorded at harvest using a digital balance. This measurement included both marketable tubers (Grade A, B and C, >25 g) and unmarketable tubers (Grade D, <25 g) and was expressed in kilograms per plot.

- **Total Tuber Yield (q/ha) :** The weight of marketable and unmarketable tubers per plot was measured and then converted to yield per hectare using an appropriate conversion factor. The total yield was expressed in quintals per hectare.

Statistical analysis

The data collected on various parameters were analyzed using the Randomized Block Design (RBD) methodology, as recommended by Gomez and Gomez (1984). The results were interpreted based on the 'F' test value and the critical difference (CD) was calculated to determine statistical significance

Results and Discussion

Total number of tubers per plant

The data on a total number of tubers per plant was significantly influenced by different concentration of growth regulators and their combination is presented in Table 1.

The total number of tubers per plant varied significantly, ranging from 6.12 to 8.19, influenced by different doses of PGR (GA_3). The highest total number of tubers per plant (8.19) was noted with the treatment application of 75%RDF+ 25% FYM+ Azotobacter (10g/ kg tuber) + GA_3 (100ppm) (T_7), which was at par with the treatment T_8, T_9, T_{10}, T_6, T_5 and T_{11}. Whereas, the lowest total number of tubers per plant (6.12) was observed in 100% RDF (T_1).

According to Paikra *et al.* (2020), who discovered that spray treatment with plant growth regulators produced the greatest number of tubers per plant (5.73) compared to seed treatment. GA_3 (100 ppm) was shown to be the most promising treatment for increasing the quantity of compound leaves in potato tubers. Additionally, Sillu *et al.* (2012) discovered that when treatment is sprayed, the number of tubers per plant (2.96) is highest, with GA_3 (100 ppm) doing the best.

Average diameter of tubers per plot (cm)

The data on the average diameter of tubers weight per plot was significantly influenced by different concentrations of growth regulators and their combination is presented in Table 2. The average diameter of tubers weight per plot varied significantly, ranging from 4.12per plot to 6.00 per plot, influenced by different doses of PGR (GA_3) and the maximum average diameter of tubers weight per plot (13.39per plot) was noted with the treatment application of 75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm) (T_7), which was at par with the treatment T_8, T_9, T_{10}, T_6, T_5, T_{11} and T_3. Whereas, the minimum average diameter of tubers weight per plot (10.07 per plot) was observed in 100% RDF (T_1).

According to Usha *et al.* (2009), cycocel sprayed foliarly on rhubarb generated rhizomes with the biggest width by inhibiting the manufacture of endogenous gibberillic acids, which suppressed shoot development and increased the allocation of photo-assimilates to the rhizomes. Abdul and Kumaran (1980), Tohamy *et al.* (2015), Shee (1983), Mohamed and Anbu (1996), Jirali *et al.* (2008), Patel *et al.* (2010), Desai *et al.* (2012), Patil and Chaitanya (2014) have all previously shown a similar reaction of CCC increasing the girth of root tuber.

Average tuber weight

The data on average tuber weight was significantly influenced by different concentrations of growth regulators and their combination is presented in Table 3.

Table 1 : Total number of tubers per plant.

S. no.	Treatment	Total number of tubers per plant
T_1	100% RDF	6.12
T_2	75%RDF+ 25% FYM	7.36
T_3	75%RDF+ 12.5% FYM+12.5% Neem Cake	7.83
T_4	50%RDF+ 25% FYM+25% Neem Cake	7.43
T_5	75%RDF+ 12.5% FYM+12.5% Neem Cake+ Azotobacter (10g/kg tuber)	6.43
T_6	75%RDF+ 12.5% FYM+12.5% Neem Cake+ GA_3 (100ppm)	7.56
T_7	75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm)	8.19
T_8	75%RDF+25% Neem Cake + Azotobacter (10g/kg tuber) + GA_3 (100ppm)	6.79
T_9	75%RDF+25% FYM + 25% Neem Cake + GA_3 (100ppm)	8.09
T_{10}	75%RDF+ 25% FYM + GA_3 (100ppm)	7.12
T_{11}	75%RDF+25% Neem Cake+ Azotobacter (10g/kg tuber)	6.92
SE(m)		0.36
C.D. @ 5%		1.03

Table- 2: Average diameter of tubers per plot (cm)

S. no.	Treatment	Average diameter of tubers per plot (cm)
T_1	100% RDF	4.12
T_2	75%RDF+ 25% FYM	4.21
T_3	75%RDF+ 12.5% FYM+12.5% Neem Cake	4.44
T_4	50%RDF+ 25% FYM+25% Neem Cake	5.26
T_5	75%RDF+ 12.5% FYM+12.5% Neem Cake+ Azotobacter (10g/kg tuber)	5.89
T_6	75%RDF+ 12.5% FYM+12.5% Neem Cake+ GA_3 (100ppm)	4.87
T_7	75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm)	6.00
T_8	75%RDF+25% Neem Cake + Azotobacter (10g/kg tuber) + GA_3 (100ppm)	5.38
T_9	75%RDF+25% FYM + 25% Neem Cake + GA_3 (100ppm)	5.74
T_{10}	75%RDF+ 25% FYM + GA_3 (100ppm)	4.56
T_{11}	75%RDF+25% Neem Cake+ Azotobacter (10g/kg tuber)	4.56
SE(m)		0.21
C.D. @ 5%		1.61

Table 3 : Average tuber weight (g).

S. no.	Treatment	Average tuber weight (g)
T_1	100% RDF	37.18
T_2	75%RDF+ 25% FYM	41.53
T_3	75%RDF+ 12.5% FYM+12.5% Neem Cake	44.56
T_4	50%RDF+ 25% FYM+25% Neem Cake	42.88
T_5	75%RDF+ 12.5% FYM+12.5% Neem Cake+ Azotobacter (10g/kg tuber)	45.47
T_6	75%RDF+ 12.5% FYM+12.5% Neem Cake+ GA_3 (100ppm)	39.81
T_7	75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm)	53.31
T_8	75%RDF+25% Neem Cake + Azotobacter (10g/kg tuber) + GA_3 (100ppm)	48.42
T_9	75%RDF+25% FYM + 25% Neem Cake + GA_3 (100ppm)	52.72
T_{10}	75%RDF+ 25% FYM + GA_3 (100ppm)	49.77
T_{11}	75%RDF+25% Neem Cake+ Azotobacter (10g/kg tuber)	47.63
SE(m)		0.25
C.D. @ 5%		0.73

The average tuber weight varied significantly, ranging from 37.18g to 53.31g, influenced by different doses of PGR (GA_3). The highest average tuber weight (53.31g) was noted with the treatment application of 75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm) (T_7), which was at par with the treatment T_8 and T_9. Whereas, the lowest average tuber weight (37.18g) was observed in 100% RDF (T_1).

Similar results were reported by Sillu *et al.* (2012), who discovered that spray treatment of plant growth regulators produced the highest average weight of tubers (61.84 g) compared to seed treatment. The treatment indicated that GA_3 (100ppm) was the most promising for increasing the average tuber weight in potato tubers.

Total tubers yield per plot (kg)

The data on total tuber yield was significantly influenced by different concentration of growth regulators and their combination are presented in Table 4. The total tuber yield varied significantly, ranging from 14.58kg/plot to 20.88kg/plot, influenced by different doses of PGR (GA_3). The highest yield (20.88kg/plot) was achieved with the treatment of 75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm) (T_7), which was at par with the treatment T_8, T_9, T_{10} and T_6. Whereas, the lowest total tubers yield (14.58kg/ plot) was observed in 100% RDF (T_1).

Results are in consensus with Singh *et al.* (2003) conducted "an experiment during winter to determine the best plant growth regulators for foliar spray to maximize seed potato yield and they discovered that plant growth regulators such as GA_3, IAA, TIBA and Ethereal significantly increased seed size (25-75g), tubers yield as well as total tuber yield. GA_3 @ 200 ppm treatment

Table 4 : Total tuber yield per plot (kg).

S. no.	Treatment	Total tuber yield per plot (kg)
T_1	100% RDF	14.58
T_2	75%RDF+ 25% FYM	15.90
T_3	75%RDF+ 12.5% FYM+12.5% Neem Cake	17.51
T_4	50%RDF+ 25% FYM+25% Neem Cake	16.57
T_5	75%RDF+ 12.5% FYM+12.5% Neem Cake+ Azotobacter (10g/kg tuber)	18.42
T_6	75%RDF+ 12.5% FYM+12.5% Neem Cake+ GA_3 (100ppm)	18.95
T_7	75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm)	20.88
T_8	75%RDF+25% Neem Cake + Azotobacter (10g/kg tuber) + GA_3 (100ppm)	20.68
T_9	75%RDF+25% FYM + 25% Neem Cake + GA_3 (100ppm)	19.93
T_{10}	75%RDF+ 25% FYM + GA_3 (100ppm)	19.77
T_{11}	75%RDF+25% Neem Cake+ Azotobacter (10g/kg tuber)	17.72
SE(m)		0.74
C.D. @ 5%		2.13

Table 5 : Total tubers yield per hectare (q).

S. no.	Treatment	Total tubers yield per hectare (q)
T_1	100% RDF	191.10
T_2	75%RDF+ 25% FYM	203.29
T_3	75%RDF+ 12.5% FYM+12.5% Neem Cake	214.46
T_4	50%RDF+ 25% FYM+25% Neem Cake	231.59
T_5	75%RDF+ 12.5% FYM+12.5% Neem Cake+ Azotobacter (10g/kg tuber)	256.28
T_6	75%RDF+ 12.5% FYM+12.5% Neem Cake+ GA_3 (100ppm)	362.39
T_7	75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm)	370.19
T_8	75%RDF+25% Neem Cake + Azotobacter (10g/kg tuber) + GA_3 (100ppm)	254.35
T_9	75%RDF+25% FYM + 25% Neem Cake + GA_3 (100ppm)	300.00
T_{10}	75%RDF+ 25% FYM + GA_3 (100ppm)	358.21
T_{11}	75%RDF+25% Neem Cake+ Azotobacter (10g/kg tuber)	239.78
SE(m)		1.96
C.D. @ 5%		5.64

resulted in the highest overall tuber production (37.0 tons/ha), followed by ethereal in compared to control (30.4 tons/ha)".

Total tubers yield per hectare (q)

The data on total tuber yield was significantly influenced by different concentration of growth regulators and their combination are presented in Table 5. The total tubers yield varied significantly, ranging from 191.10q/ha to 370.19q/ha as influenced by different doses of PGR (GA_3). The highest yield (370.19q/ha) was noted with the treatment application of 75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm) (T_7), which was at par with the treatment T_8, T_9, T_{10} and T_6. Whereas, the lowest total tubers yield (191.10q/ha) was observed in 100% RDF (T_1).

Results reported by Birbal *et al.* (2009) as performed a field experiment aimed at optimizing seed potato production, and various foliar spray plant growth regulators including GA_3, NAA, TIBA and Ethrel were evaluated. The results indicated that these growth regulators significantly increased seed yield (25-75 g) and total tuber yield. Specifically, the GA_3 treatment at 200 ppm resulted in the highest tuber yield of 37.0 tonnes per hectare, followed closely by Ethrel with a yield of 35.0 tonnes per hectare, compared to the control which yielded 30.4 tonnes per hectare.

Effect of different treatments on yield parameters of Potato

The investigation revealed that the treatment T_7(75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm)is the best application of different treatments and it gave the maximum yield parameters (viz., total tuber yield per plot(kg), total tuber yield per hectare(q), total number of tuber per plant, average tuber

weight(g), average diameter of tubers per plot) were found in treatment T_7 (75%RDF+ 25% FYM+ Azotobacter (10g/kg tuber) + GA_3 (100ppm) and it was significantly superior to other treatments while the minimum yield parameters were recorded in treatment T_1(100% RDF). The application of FYM, Azotobacter, Neem cake and Gibberellic acid might have significantly enhanced the availability of native and applied macro and micro nutrients, vitamins, enzymes, antibiotics, growth hormones and insoluble nutrients to the plants, as consequence of which increase the yield of potato tubers and plant. FYM and Azotobacter improve soil structure and fertility, creating a better root environment. GA_3 enhances growth and tuber decvelopment, leading to improved yield parameters. The results are in confirmation with the results achieved by Kumar *et al*. (2012), Sarma and Sarkar (2008), Paikra *et al*. (2020), Sillu *et al*. (2012), Bribal *et al*. (2009), Javanmadir and Rasuli (2017) Prakash*et al*. (2001), Pandita *et al*. (1981), Singh *et al*. (2003), Benerjee and Das (1984), Alexander *et al*. (2011).

Conclusion

This study, titled "Effect of Gibberellic Acid, Azotobacter and Neem Cake on Yield of Potato (*Solanum tuberosum* L.) under Gwalior Region" has provided valuable insights into the optimal agronomic practices for enhancing potato cultivation in the specific climatic conditions of Gwalior.

The experimentation, conducted using a Randomized Block Design with eleven different treatment combinations, revealed significant findings regarding the growth, yield and quality parameters of the potato variety Kufri Pukhraj. Key conclusions drawn from the study include:

- **Significant Impact of Treatments**: The various treatments incorporating Gibberellic acid, Azotobacter, Neem cake, FYM (Farm Yard Manure), and different doses of recommended fertilizers significantly influenced the yield parameters such as total number of tubers per plant, tuber diameter, average tuber weight, total tuber yield per plot, and total tuber yield per hectare.
- **Superior Performance of T7 Treatment**: The treatment T_7 (75% RDF + 25% FYM + Azotobacter (10g/kg tuber) + GA_3 (100ppm)) consistently outperformed other treatments, resulting in the highest total tuber yield per plot (20.88 kg), highest total tuber yield per hectare (370.19 q/ha), the highest number of tubers per plant (8.19), highest average tuber weight (53.31 g) and largest average tuber diameter per plot (6.00 cm). This treatment also yielded the maximum net returns (Rs 265393/ha) and demonstrated a high benefit-cost ratio.
- **Economic Viability**: Besides achieving superior yield and growth parameters, the treatment T_7 was economically viable, providing the highest net returns. The treatments T_8 (75% RDF + 25% Neem cake + Azotobacter (10g/kg tuber) + GA_3 (100ppm)) and T_7 both recorded the highest benefit-cost ratio (2.53), underscoring their potential for economic sustainability in potato farming.
- **Effectiveness of Integrated Approaches**: The integration of organic amendments like FYM and Neem cake with biological agents (Azotobacter) and plant growth regulators (Gibberellic acid) proved to be highly effective. Such integrated approaches not only enhance yield but also contribute to sustainable agricultural practices, the findings from this research highlight the importance of using a combination of organic, biological and chemical inputs to optimize potato production in Gwalior's subtropical climate. The superior performance of the T_7 treatment provides a practical guideline for farmers seeking to maximize both yield and economic returns. These insights can significantly contribute to sustainable potato cultivation practices, ultimately benefiting the agricultural sector in similar agro-climatic regions.

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