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# Potato Tuber Eye Explant Growth Performance as Affected by some Growth Regulators

**El-Areiny, A. A. R.[1]; A. A. Alkharpotly[2*]; A. A. A. Gabal[1] and M. A. Aly[1]**

[1]Pl. Prod. Dept., Fac. Agric. (Saba Bash), Alex. Univ., Egypt
[2]Hort. Dept., Fac. Agric. & Natur. Reso., Aswan Univ., Egypt
[2]Hort. Dept., Fac. Desert & Envir. Agric., Matrouh Univ., Egypt

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## ABSTARCT

The experimental were conducted during the two successful summer seasons of 2019/2020 and 2020/2021, in a private farm, at Abu Al- Matamir city, Al-Behiera Governorate, Egypt, under open field condition, with surface irrigation system aiming to evaluate the response of potato tubers "Cara cultivar" to soaking before planting in "NAA" as auxin and synthetic cytokinin "CPPU" and the effects on vegetative growth, yield and its components and quality as well as the production of safe and economic potato tubers. The treatments comprising two times of soaking *i.e.*, 5 and 10 min as main plot, three concentration treatments of (CPPU) as synthetic cytokinin *i.e.*, 0.0, 5.0, 10.0 mg $L^{-1}$) as sub plot and three levels of NAA as auxin (0, 5 and 10 mg $L^{-1}$).The results indicated that soaking cut tuber explants before planting for 10 min in growth regulators solution was more superior for increasing vegetative growth parameters such as plant height, number of leaves and branches , yield (average tuber weight, number of tuber and total yield ton.$fed^{-1}$), tuber quality (starch, TSS and total sugars %) and nutrition values in leaves and tubers (N, P and K%). Moreover, soaking in 10 mg $L^{-1}$ CPPU mixed with 10 mg $L^{-1}$ NAA for each of 5 or 10 min. increased all mentioned parameters. Generally, it could be concluded that soaking cut tuber explants of potato in 10 mg $L^{-1}$ CPPU mixed with 10 mg $L^{-1}$ NAA for 10 min before planting gave highest gross and economic yield of potato plants.

***Keywords**:* NAA, CPPU, Soaking, potato plant.

## INTRODUCTION

One of the most frequently cultivated commercial food crops worldwide is the potato (*Solanum tuberosum* L.) with a total global cultivation area of around 20 million hectares, it comes in third behind rice and wheat (FAO, 2016, Soliman *et al.*, 2022 and El-Sherpiny *et al.*, 2022). The Egyptian potato production for 2018 was estimated at 4,896,476 tonnes, coming from 176,670 feddans (FAOSTAT, 2018), which represents roughly 1% of the global production, according to the Food and Agriculture Organization of the United Nations (FAO, 2018). The global total production of potato tubers was estimated to be 388,190,674 tonnes in 2017, harvested from a region that came to about 17.580 million hectares (ha). Thus, one of the most significant solanaceous vegetables grown in Egypt as a top exportable and cash vegetable crop is the potato. From a nutritional standpoint, potatoes are a significant, low-cost energy source that contain fiber, carbohydrates, protein, minerals, and little to no fat (Navarre *et al.*, 2009; McGill *et al.*, 2013). As a result, they are used in many commercial activities, including the production of chips and French fries, alcohol, and starches.

Since productivity is heavily influenced by factors including temperature, moisture, soil composition, and light intensity, the world's annual potato production now falls short of meeting the needs of the world's ever-increasing population. Although there is a wide variety of growth regulators that are suggested for use on potatoes, these regulators do not fully support the functional requirements of the plants' growth and development, therefore both functional and technological application parameters need to be improved (Nazranov *et al.*, 2020). This study used soaking tubers before planting with stimulants to promote growth, productivity of potato, and decrease number of days needed for days to germination, and therefore harvesting this led to an earlier yield (Sawan *et al.*, 2000; Abd El-Hady and Shehata, 2019; Hamaiel *et al.*, 2021) compared to a foliar application (Sillu *et al.*, 2012). The kind and quantity of growth regulators are two elements that have an impact on plant production. It was therefore predicted in this work that soaking of synthetic cytokinin in the form of phenylurea cytokinin's (CPPU; N-(2- chloro-4-pyridyl)-N-phenylurea), and Auxin as naphthalene acetic acid (NAA) could be crucial in this situation.

Plant growth regulators are the organic substances other than nutrients that, in little doses, enhance or regulate a plant's physiological processes. The concentration of plant growth regulators, method, and timing of application can all significantly improve yield and quality (Gurjar *et al*. 2018), with cytokinin being the most significant of these regulators due to its variety of functions. For potato vegetative and rooting growth, the medium supplemented with various hormone kinds and concentrations has produced a range of outcomes. According to prior research, the best method for growing potato shoots was a mix of BAP and NAA (Ahmed *et al*., 2021).

An essential plant hormone called cytokinin (CK) drives vigorous cell division and significantly affects how plant organs form and change over time, particularly how shoots change over time (Werner *et al*., 2001; Amoo *et al*., 2014). Additionally influencing metabolic activities such the production of nucleic acids, proteins, and chlorophyll, this plant

* **Corresponding author.**
**E-mail address: abdelbaseetalkharpotly@gmail.com**
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hormone controls physiological processes in plants (Merewitz *et al*., 2012). High chlorophyll concentration prolongs the greenness of the leaves, which allows more nutrients to be delivered and transduced to cellular targets for leaf growth. It regulates plant senescence and the prevention of plant senescence (Chernyadyev, 2009). Synthetic cytokinin such as 6-Benzylaminopurine, benzyl adenine (BAP or BA) can improve plant growth by cell division, break bud dormancy and promotes the growth of the lateral bud (Hossain *et al*. 2006).

The production of high-quality fruits and vegetables depends heavily on naphthalene acetic acid (NAA). NAA is being used to boost up the remarkable vegetative propagation. By accelerating cell elongation, cell division, and cell differentiation-processes that could start the creation of plant organs-NAA aids in the growth of plants. Additionally, it is crucial for the development of root cambium and epicycle, which may lead to the emergence of lateral roots. It's also noteworthy that NAA improved flowering, heavy fruit setting, and reduced young embryo abortion and fruit drop. It also affects the physiological process, hasten maturity, and produces better quality fruits and some other aspects such as to increase the number of branches, increased fresh weight, and yield as well as induces early flowering and prevents flower and fruit drop (Gurjar *et al*., 2018; Surendar *et al*., 2020).

Through this investigation, it was decided to evaluate soaking potato tubers in growth-regulators like synthetic cytokinin called CPPU and auxin as (NAA) at different concentrations and their interactions in order to improve yields and financial returns to potato growers. This is done in order to develop good management practices for potato growers in Egypt.

## MATERIALS AND METHODS

The experimental were conducted during the two successful summer seasons of 2019/2020 and 2020/2021, in a privet farm, at Abu Al- Matamir city, Al-Behiera Governorate, Egypt, under open field condition, with surface irrigation system aiming to evaluate the response of potato plant "Cara cultivar" to soaking before planting in *α*-naphthaleneacetic acid "NAA" and synthetic cytokinin CPPU "N-(2-chloro-4-pyridyl)-N'-phenyl urea" on vegetative growth, yield and its components and quality as well as the production of safe and economic potato tubers.

Random soil samples of 0-30 cm depth from various locations in the planting field were collected and examined before planting for key crucial chemical and physical qualities, as shown in Table (1).

The utilized seed tubers (cv Cara.) were sliced into explants weighing around 40 g, and each explant had two eyes, then soaked for 5 or 10 min in all treatments. During both seasons 2019/2020 and 2020/2021 tubers were planted on the 1st of Jan. under a surface irrigation system at 20 cm apart in the row and 0.8 m width in dry soil then irrigated (Fed. 4000 $m^2$= 25000 plants). Experimental plot area was 10.5 $m^2$.

The physical and chemical analyses were carried out at the Soil and Agricultural Chemistry Departement, The Faculty of Agriculture (Saba Basha), Alexandria University, Egypt.

Eighteen treatments were arranged in split-split plot system in a randomize complete bloke design (RCBD) with 3 replicates which were the simple possible combination between 2 times of soaking (5 and 10 min) as main plot, 3 concentration treatments of (CPPU) as synthetic cytokinin (0, 5, 10 mg $L^{-1}$) as sub plot and 3 levels of (NAA) as auxin (0, 5 and 10 mg $L^{-1}$), which distributed randomly within each block. Thus, the total number of experimental unites were 54 plots.

**Table 1. Some physical and chemical properties of the experimental site during both seasons of the experimentation (2019-2020 and 2020-2021).**

| Soil properties | Season 2019-2020 | Season 2020-2021 |
|---|---|---|
| Mechanical Analysis: | | |
| Clay (%) | 14.57 | 14.63 |
| Silt (%) | 8.14 | 7.67 |
| Sand (%) | 77.29 | 77.70 |
| Textural class | Sandy clay | Sandy clay |
| Chemical analysis: | | |
| pH (1:2 water suspension) | 8.21 | 8.36 |
| EC at 25° C (dS/m) | 0.32 | 0.26 |
| Soluble cations in (1:5) soil: water extract (meq/l) | | |
| $Ca^{++}$ | 0.27 | 0.33 |
| $Mg^{++}$ | 0.34 | 0.32 |
| $K^+$ | 0.39 | 0.34 |
| $Na^+$ | 1.90 | 1.98 |
| Soluble anions in (1:5) soil: water extract (meq/l) | | |
| $HCO_3^-$ | 1.24 | 1.19 |
| $Cl^-$ | 0.81 | 0.87 |
| $SO_4^{--}$ | 0.84 | 0.88 |
| Available N (mg/kg soil) | 10.26 | 13.14 |
| Available P (mg/kg soil) | 32.54 | 36.23 |
| Available K (mg/kg soil) | 365.41 | 387.64 |

Ten samples of each plot were randomly taken after 85 days and carried immediately to the laboratory. Vegetative growth parameters were expression of; Plant height (cm), number of leaves per plant and number of branches per plant.

After 120 days (harvesting), a random sample of 10 plants from each experimental plot were taken for determination of tuber measurement *i.e.*, number of tubers per plant, average of tuber fresh weight (g) and total tubers yield per feddan (ton).

Chemical quality tubers: TDS % was estimated in the juice of the fresh tubers using a hand refractometer according to AOAC (1992), starch and total sugars were determined for each tuber sample according to the method described by Malik and Singh (1980).

Nutration values of leaves and tubers as: in leaves were determined in the 4th top leaves of 10 random samples at 85 days after planting, in tuber at the harvesting period (120 days of planting), N, P and K contents were determined according to Chapman and Pratt (1978), Singh *et al*. (2005) and (Jackson, 1973), respectively.

All obtained data of the present study were, statistically, analyzed according to the design used by the CoSTATE computer software program. LSD test at 0.05 of probability and Duncan Muliple Range Test were used to compare the differences among the means of the various treatment combinations.

## RESULTS AND DISCUSSION

**Vegetative growth parameters of potato plant**:

Data in Table 2 show the effect of soaking time before planting on plant height, leaves and branch number. Vegetative growth parameters were increased significantly with increasing the soaking time from 5 to 10 min and the best values were recorded with soaking in 10 min then 5 min with no significant effect between 5 and 10 min in the 1st season for plant height and had no significant effect on branches number during both seasons.

Concerning the effect of synthetic cytokinin CPPU on vegetative growth parameters of potato plant, the data of Table (2) show a significant increase in mentioned parameters for the plants soaked in different concentrations of CPPU over that obtained from the untreated plants. In this respect, the highest mean values were (92.02-97.71 cm), (89.09-94.66) and (3.22-3.17) in the 1st and 2nd seasons, respectively for 10 mg $L^{-1}$ CPPU.

Regarding the effect of soaking in naphthaleneacetic acid "NAA" on vegetative growth parameters, data in Table (2) revealed that soaking the tuber of potato with different concentrations (0, 5 and 10 mg $L^{-1}$) from NAA significantly increased the mean values of vegetative growth parameters under study than those obtained for the untreated ones. In the same line, the highest mean values recorded with the plants soaked with 10 mg $L^{-1}$ NAA. The same trend was the same during both seasons.

Concerning the effect of the combination between the soaking time, CPPU and NAA data in Table (2) indicate that the highest values of potato vegetative growth parameters were recorded with the tubers soaked in 10 mg $L^{-1}$ from both CPPU and NAA for 10 min before planting followed by the same treatment at 5 min with a significant difference between the treatments during both seasons.

**Table 2. Averages values of plant height, number of leaves and branches/plant of potato plants as affected by soaking in synthetic cytokinin (CPPU), auxin (NAA) and their combinations during the summer seasons of 2019/2020 and 2020/2021.**

| Treatments | | | Plant height (cm) | | No. of leaves/plant | | No. of branches/plant | |
|---|---|---|---|---|---|---|---|---|
| | | | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 |
| Soaking time | | | | | | | | |
| 5 min | | | 86.62a | 91.82b | 78.96b | 83.70b | 2.52a | 2.56a |
| 10 min | | | 87.60a | 93.21a | 83.48a | 88.76a | 2.56a | 2.67a |
| CPPU concentration mg $L^{-1}$ | | | | | | | | |
| 0 | | | 81.55c | 86.71c | 73.64c | 78.17c | 1.94c | 2.00c |
| 5 | | | 87.76b | 93.13b | 80.94b | 85.86b | 2.44b | 2.67b |
| 10 | | | 92.02a | 97.71a | 89.09a | 94.66a | 3.22a | 3.17a |
| NAA concentration mg $L^{-1}$ | | | | | | | | |
| 0 | | | 82.91a | 88.08c | 72.08c | 76.53c | 2.00b | 2.06b |
| 5 | | | 87.85b | 93.29b | 85.13b | 90.25b | 2.72a | 2.72a |
| 10 | | | 90.58c | 96.19a | 86.46a | 91.91a | 2.89a | 3.06a |
| Time | CPPU$^{-1}$ | NAA mg $L^{-1}$ | | | | | | |
| 5 min | 0 | 0 | 78.16q | 83.11j | 63.53q | 67.61l | 1.67ef | 1.67d |
| | | 5 | 80.46op | 84.75j | 67.20o | 70.90k | 2.00def | 2.00cd |
| | | 10 | 84.47kl | 89.45hi | 74.81l | 79.20i | 2.33c-f | 2.33bcd |
| | 5 mg $L^{-1}$ | 0 | 82.47mn | 87.54i | 71.10n | 75.32j | 1.67ef | 2.00cd |
| | | 5 | 88.65gh | 94.41ef | 82.50h | 87.70fg | 2.67b-e | 2.67a-d |
| | | 10 | 90.72ef | 96.46cde | 86.47f | 91.97e | 2.67b-e | 3.00abc |
| | 10 mg $L^{-1}$ | 0 | 86.65ij | 91.49gh | 78.78j | 83.25h | 2.33c-f | 2.33bcd |
| | | 5 | 92.96cd | 98.54bc | 90.26d | 95.54d | 4.00a | 3.33ab |
| | | 10 | 95.05ab | 100.67ab | 96.02a | 101.80ab | 3.33abc | 3.67a |
| 10 min | 0 | 0 | 79.28pq | 84.80j | 65.48p | 70.01k | 2.00def | 1.67d |
| | | 5 | 81.46no | 87.31i | 94.10b | 99.75bc | 1.33f | 2.00cd |
| | | 10 | 85.50jk | 90.83h | 76.72k | 81.56h | 2.33c-f | 2.33bcd |
| | 5 mg $L^{-1}$ | 0 | 83.39lm | 88.33i | 72.82m | 77.12ij | 2.00def | 2.00cd |
| | | 5 | 89.65fg | 94.90def | 84.36g | 89.35f | 2.67b-e | 3.00abc |
| | | 10 | 91.68de | 97.16cd | 88.37e | 93.69de | 3.00a-d | 3.33ab |
| | 10 mg $L^{-1}$ | 0 | 87.53hi | 93.18fg | 80.79i | 85.86g | 2.33c-f | 2.67a-d |
| | | 5 | 93.91bc | 99.80b | 92.35c | 98.27c | 3.67ab | 3.33ab |
| | | 10 | 96.04a | 102.59a | 96.35a | 103.22a | 3.67ab | 3.67a |

**Values having the same alphabetical letter (s) in common, within each column in each group, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.**

The many roles that cytokinins and their derivatives play in CPPU's enhanced foliar application as a synthetic cytokinin can be explained. Additionally, it plays a part in promoting cell division, bud development, and tip meristem proliferation. Giving additional CPPU results in an increase in the number of buds that are generated (Chaudhary and Mitta, 2014). Additionally, according to George *et al.* (2008), cytokinins disrupt apical dominance, drive cell division, regulate morphogenesis, and awaken dormant lateral buds from their dormancy. These results are in agreement with those obtained by Abd El-Hady *et al.* (2016) showed that soaking tubers per planting in BAP at the rate of 50 mg $L^{-1}$ and sprayed with the same concentration after planting increased significantly height of plant (cm); No of branches/ plant; No of leaves/ plant and fresh weight (g/plant). Also, Brengi (2018) reported that spraying BAP at 50 ppm resulted in the greatest mean values of vegetative growth, increased plant height, number of leaves, number of branches, and leaf area plant$^{-1}$. On the other hand, all synthetic cytokinins under high temperature circumstances increased the typical number of days from planting to the first blossom compared to control treatment. In addition, Ahmed *et al.* (2021) reported that foliar application treatments of BA as cytokinin at the rate of 100 mg $L^{-1}$ significantly increased vegetative growth characters as plant height, fresh and dry of potato plants during both seasons.

The physiological effects of auxins on plant development parameters, which cause cell division and cell elongation and lead to greater plant growth, may account for the considerable influence of NAA seen in this experiment. Similar findings were made by Prasad *et al.* (2013), who discovered that the amount of NAA linearly increased with plant height and the number of branches per plant. After 60 days of transplanting, the maximum plant height was measured as 82.3 cm with the treatment of NAA at 100 ppm. Also, Singh *et al.* (2017), NAA at 60 ppm boosted the pepper plant's plant height (120.59 cm), number of branches (16.05 cm), plant spread (92.57 cm), days before the first blooming (32.51), and flower count per plant (11.83). Ahmed *et al.* (2021) resulted that foliar application treatments of auxin (NAA) at the rate of 100 mg $L^{-1}$ significantly increased vegetative growth characters as plant height, fresh and dry of potato plants during both seasons. Additionally, Bhattarai *et al.* (2021) reported that addition of ppm NAA was the best to have better results for plant number of branches, stem diameter, main root length, and fruit weight.

**Yield characters and its components:**

Data illustrated in Table (3) indicate the effect of soaking time on average weight, number of potato tuber and total yield ton fed$^{-1}$ for 5 and 10 min. Data had no significant effect between 5 and 10 min but generally, the highest mean values of mentioned parameters recorded with 10 min.

Statistical analysis of the data presented in Table (3) indicate that treatments of CPPU under study affected on the mentioned parameters. It is evident that the highest values of average weight, number of potato tuber and total yield ton fed$^{-1}$ associated with plants soaked in 10 mg $L^{-1}$ before planting. The increase in concentrations of CPPU significantly increased the average weight and total yield ton fed$^{-1}$ during both seasons, while tuber number recorded no significant effect during both seasons.

Concerning the effect of NAA at different concentrations, data in the same table illustrated that, soaking the tubers of potato in NAA before planting significantly increased the mean values of average weight, number of potato tuber and total yield ton fed$^{-1}$ than those obtained for the untreated plants. Using 10 mg $L^{-1}$ was superior for increasing the aforementioned trait in two seasons.

It is clear from the data presented in Table (3) that interaction effect between soaking time, CPPU and NAA significantly increased average weight, number of potato tuber and total yield ton fed$^{-1}$ than those obtained for the untreated plants. The highest mean values were obtained with the treatment of 10 mg $L^{-1}$ of both CPPU and NAA when soaked for 10 min. The same trend was realized for two seasons.

The increase in yield due to soaking in CPPU agree with Gora *et al.* (2018) found that, in oilseed crops, an addition of benzyl adenine improved the yield. Significant increase in seed yield of could be ascribed to cumulative effect of yield components *viz.*, number of fruit, number of seeds and test weight which increased seed yield and ultimately led to greater seed production per unit area. Also, Lahijani *et al.* (2018) discovered that as compared to the control treatment, using BAP+ABA increased the tuber yield of the "Agria" cv. by 20%, while using ABA increased the tuber yield of the "Fontane" cv (21 %). In contrast to the control plants, the BAP+ABA treatment for the "Agria" cv. significantly increased mean tuber weight by 28%. Contrarily, when compared to the control plants, BAP use increased the mean tuber weight of the "Fontane" cv. by 28%. In addition, Ahmed *et al.* (2021) reported that potato tuber yield and its components expressed in (tuber length (cm), tuber diameter (cm), tuber shape index, number of tubers, average weight of tuber and total yield) significantly increased with increasing BA as cytokinin concentration and the highest values recorded with the foliar application with 100 mg $L^{-1}$.

**Table 3. Averages values some yield characters of potato tuber as affected by soaking in synthetic cytokinin (CPPU), auxin (NAA) and their combinations during the summer seasons of 2019/2020 and 2020/2021.**

| Treatments | | | Average tuber weight g/plant | | Number of tuber/plant | | Total yield/feddan (ton) | |
|---|---|---|---|---|---|---|---|---|
| | | | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 |
| Soaking time | | | | | | | | |
| 5 min | | | 159.48a | 164.87a | 5.10a | 5.11a | 20.33a | 21.04a |
| 10 min | | | 161.93a | 166.98a | 5.09a | 5.10a | 20.61a | 21.29a |
| CPPU concentration mg $L^{-1}$ | | | | | | | | |
| 0 | | | 149.87c | 154.60c | 5.14a | 5.13a | 19.24c | 19.82c |
| 5 | | | 162.26b | 167.46b | 5.10a | 5.10a | 20.68b | 21.36b |
| 10 | | | 170.00a | 175.72a | 5.06a | 5.08a | 21.49a | 22.31a |
| NAA concentration mg $L^{-1}$ | | | | | | | | |
| 0 | | | 152.69c | 157.71c | 5.13a | 5.13a | 19.59c | 20.22c |
| 5 | | | 162.21b | 167.16b | 5.09a | 5.11ab | 20.65b | 21.36b |
| 10 | | | 167.24a | 172.90a | 5.07a | 5.07b | 21.17a | 21.91a |
| Time | CPPU$^{-1}$ | NAA mg $L^{-1}$ | | | | | | |
| 5 min | 0 | 0 | 143.39p | 148.50p | 5.16a | 5.13ab | 18.51o | 19.04l |
| | | 5 | 147.63no | 152.60o | 5.14a | 5.12ab | 18.98mno | 19.52k |
| | | 10 | 155.59jk | 160.24kl | 5.11a | 5.12ab | 19.89ijk | 20.50hi |
| | 5 mg $L^{-1}$ | 0 | 151.80lm | 156.16mn | 5.13a | 5.14ab | 19.48klm | 20.05j |
| | | 5 | 164.06fg | 168.85gh | 5.10a | 5.15ab | 20.91efg | 21.72ef |
| | | 10 | 167.93de | 173.91ef | 5.07a | 5.06b | 21.27cde | 22.00de |
| | 10 mg $L^{-1}$ | 0 | 159.60hi | 164.52ij | 5.12a | 5.14ab | 20.41gi | 21.13g |
| | | 5 | 171.98bc | 177.50cd | 5.06a | 5.07ab | 21.75bc | 22.48c |
| | | 10 | 173.39bc | 181.53ab | 5.02a | 5.05b | 21.77bc | 22.93ab |
| 10 min | 0 | 0 | 145.64op | 150.53op | 5.16a | 5.14ab | 18.78no | 19.33kl |
| | | 5 | 149.47mn | 153.42no | 5.13a | 5.18a | 19.16lmn | 19.85j |
| | | 10 | 157.54ij | 162.33jk | 5.11a | 5.10ab | 20.13hij | 20.71h |
| | 5 mg $L^{-1}$ | 0 | 153.69kl | 158.84lm | 5.14a | 5.14ab | 19.73jkl | 20.39i |
| | | 5 | 165.75ef | 171.40fg | 5.10a | 5.10ab | 21.12def | 21.85de |
| | | 10 | 170.32cd | 175.59de | 5.06a | 5.04b | 21.54bcd | 22.14d |
| | 10 mg $L^{-1}$ | 0 | 162.00gh | 167.73hi | 5.10a | 5.11ab | 20.64fgh | 21.41fg |
| | | 5 | 174.36b | 179.20bc | 5.04a | 5.08ab | 21.95ab | 22.75bc |
| | | 10 | 178.65a | 183.82a | 5.02a | 5.04b | 22.42a | 23.18a |

**Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.**

While the increment in total and marketable yield attributed to soaking tuber before planting in to NAA are in agreement with those obtained by several authors Singh *et al.* (2017) observed that NAA at 60 ppm increased fruit weight (169.66g), the number of fruits per plant (9.87), the number of seeds per fruit (110.78), the number of fruits produced per plant (1.67kg), the number of fruits produced per plot (15.07kg), and the number of fruits produced per hectare (69.76t), According to the aforementioned finding, NAA at 60 ppm is extremely favorable for the growth and yield of capsicum. Also, Chanwala *et al.* (2019), applying NAA at 180 ppm to sprouting broccoli considerably enhanced both the total yield/hectare

(198.25 q) and the total yield per plot (6.42 kg). Additionally, Malek *et al.* (2021) reported that foliar application with 30 mg $L^{-1}$ CPPU significantly increased the No. of tubers per 10 kg, tuber fresh weight (g $plant^{-1}$), No. of tubers per plant, total yield per plant (g and ton $fed^{-1}$).

**Tuber chemical quality characteristics**

Regarding the effect of soaking time, NAA and CPPU on tuber chemical quality of potato plant as (starch, TSS and total sugar%) are presented in Table (4) during both seasons of 2019/2020 and 2020/2021.

The result in Table (4) clearly shows a significant effect in the two seasons on starch, TSS and total sugar% as affected by the soaking time (5 and 10 min). According to the data, soaking for 10 min was the most effective in starch, TSS and total sugar% content and recorded the highest mean values comparing to the control during both seasons.

Data presented in the same table reveal that soaking in CPPU as synthetic cytokinin at different concentrations (5, 10 mg $L^{-1}$) comparing to the control significantly affected in starch, TSS and total sugar% content in potato tuber. Soaking in CPPU increased content of starch, TSS and total sugar% and the highest mean value was at 10 mg $L^{-1}$ as (20.76-21.49 %), (7.10-7.54%) and (6.67-7.00%), respectively during both seasons.

Result in Table (4) show a significant effect on tuber quality content during both seasons due to soaking in different concentrations of NAA. It can be reported that, the highest mean values of starch, TSS and total sugar% content was obtained from plants soaking in 10 mg $L^{-1}$ NAA comparing to the lowest mean values which recorded with the untreated plant. The same trend was true during both seasons.

The interaction among the soaking time, CPPU and NAA had a significant effect on the potato starch, TSS and total sugar% content in the two seasons as presented in Table (4). It is clear that soaking in 10 mg $L^{-1}$ from each CPPU and NAA for 5 or 10 min was the effective treatment to increase the starch, TSS and total sugar% content but soaking for 10 min was the most effective to record the highest mean values during both seasons.

The positive effect due to soaking in CPPU on tuber chemical quality under investigation are in accordance with that obtained by Rosin *et al.* (2003) on potato, claimed that antisense inhibition of the potato box gene caused an increase in cytokinin levels, which in turn caused larger increments of starch accumulation. Also, according to El-Shraiy and Hegazi (2010), cytokinin treatments at 10 ppm dramatically increased the total soluble sugars in potato tubers. Moreover, On tomato, Mousawinejad *et al.* (2014) published that foliar application of CPPU as cytokinin at 10 and 20 mg/l on the fruit affected, significantly on sugar content. Abd El-Hady *et al.* (2016) showed that soaking tubers per planting in BAP at the rate of 50 mg $L^{-1}$ and sprayed with the same concentration after planting increased significantly reducing, non-reducing, total sugars, TSS, starch, vitamin C and protein contents. In addition, Ahmed *et al.* (2021) and Malek *et al.* (2021) on potato plant found an increase in total carbohydrates%, starch%, TSS%, vitamin C $mg.100g^{-1}$, phenols and tuber sugars% due to increasing BA concentration during both seasons.

**Table 4. Averages values of starch, TSS and total sugar% of potato tuber as affected by soaking in synthetic cytokinin (CPPU), auxin (NAA) and their combinations during the summer seasons of 2019/2020 and 2020/2021.**

| Treatments | | | Starch % | | TSS% | | Total sugars% | |
|---|---|---|---|---|---|---|---|---|
| | | | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 |
| Soaking time | | | | | | | | |
| 5 min | | | 19.67b | 20.31a | 6.46b | 6.85b | 6.02b | 6.30b |
| 10 min | | | 19.86a | 20.52a | 6.55a | 6.99a | 6.13a | 6.46a |
| CPPU concentration mg $L^{-1}$ | | | | | | | | |
| 0 | | | 18.62c | 19.19c | 5.86c | 6.23c | 5.40c | 5.67c |
| 5 | | | 19.91b | 20.56b | 6.55b | 6.97b | 6.14b | 6.47b |
| 10 | | | 20.76a | 21.49a | 7.10a | 7.54a | 6.67a | 7.00a |
| NAA concentration mg $L^{-1}$ | | | | | | | | |
| 0 | | | 18.90c | 19.50c | 6.01c | 6.38c | 5.58c | 5.85c |
| 5 | | | 19.90b | 20.58b | 6.59b | 7.00b | 6.14b | 6.47b |
| 10 | | | 20.49a | 21.17a | 6.91a | 7.36a | 6.50a | 6.82a |
| LSD at 5% | | | 0.07 | 0.21 | 0.04 | 0.07 | 0.05 | 0.05 |
| Time | $CPPU^{-1}$ | | | | | | | |
| 5 min | 0 | 0 | 17.97n | 18.49k | 5.53n | 5.89l | 5.02l | 5.27n |
| | | 5 | 18.35m | 18.91jk | 5.72m | 6.03l | 5.24k | 5.47m |
| | | 10 | 19.25j | 19.86gh | 6.22j | 6.58i | 5.75hi | 6.01k |
| | 5 mg $L^{-1}$ | 0 | 18.83k | 19.34ij | 5.92l | 6.28jk | 5.50j | 5.75l |
| | | 5 | 20.12f | 20.86de | 6.72g | 7.15fg | 6.29f | 6.62g |
| | | 10 | 20.55e | 21.25cd | 6.91e | 7.35de | 6.52e | 6.84f |
| | 10 mg $L^{-1}$ | 0 | 19.65h | 20.35fg | 6.42i | 6.78h | 6.02g | 6.30i |
| | | 5 | 20.92d | 21.58bc | 7.21d | 7.63c | 6.78cd | 7.10d |
| | | 10 | 21.36b | 22.13a | 7.48b | 7.92b | 7.02b | 7.36b |
| 10 min | 0 | 0 | 18.13n | 18.65k | 5.58n | 5.96l | 5.13kl | 5.40m |
| | | 5 | 18.56l | 19.21ij | 5.80m | 6.21k | 5.40j | 5.70l |
| | | 10 | 19.45i | 20.01gh | 6.33i | 6.72hi | 5.88h | 6.17j |
| | 5 mg $L^{-1}$ | 0 | 18.96k | 19.61hi | 6.04k | 6.40j | 5.64i | 5.91k |
| | | 5 | 20.27f | 20.97de | 6.80fg | 7.21ef | 6.25f | 6.70g |
| | | 10 | 20.72e | 21.34cd | 6.90ef | 7.45d | 6.66d | 6.97e |
| | 10 mg $L^{-1}$ | 0 | 19.85g | 20.55ef | 6.58h | 6.99g | 6.17f | 6.49h |
| | | 5 | 21.16c | 21.92ab | 7.32c | 7.79bc | 6.88c | 7.22c |
| | | 10 | 21.65a | 22.42a | 7.60a | 8.14a | 7.17a | 7.56a |

**Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.**

The results of increasing tuber chemical quality due to soaking in NAA are in harmony with those obtained by Thapa *et al.* (2013) mentioned that combination of NAA (30 mg/l) and GA3 (30 mg/l) produced the best results in the content of total sugar of broccoli. Additionally, El-Areiny *et al.* (2019) resulted that potato plants treated with 0.12 mM as foliar application of

NAA; gave the highest significant average values for tubers TSS, total phenols, starch, reducing sugars, non-reducing sugars, and total sugars compared to control plants measurements. Also, Ahmed *et al.* (2021) observed that with increasing concentration of NAA (25, 50 to 100 mg $L^{-1}$) significantly increased total carbohydrates%, starch%, TSS%, vitamin C mg.$100g^{-1}$ and tuber sugars% except total phenol of potato plant.

**Nutrition values of leaves and tubers:**

Data presented in Table (5) indicate the effect of soaking time, CPPU and NAA as well as their interactions on N, P and K% of potato leaves and tubers during both seasons.

Data tabulated in Table (5), reveal that N, P and K% of potato leaves and tubers increased significantly with increasing soaking time from 5 to 10 min. The highest mean values of nutrition values of leaves and tuber scored with soaking for 10 min during both seasons.

Data tabulated in Table (5) indicate that the average values N, P and K% of potato leaves and tubers were significantly increased with increasing concentration of CPPU from 5 to 10 mg $L^{-1}$ and the highest mean values was recorded with 10 mg $L^{-1}$ as (3.18 and 3.39%), respectively during both seasons

Results in Table (5) demonstrated the effect of NAA as auxin on N, P and K% of potato leaves and tubers. With increasing concentration of NAA (5 to 10 mg $L^{-1}$) significantly increased N, P and K% of potato leaves and tubers during both seasons. On the other words, the highest mean values were (3.09-3.30), (0.314-0.324) and (3.44-3.48) for N, P and K% in leaves and (2.37-2.52), (0.263-2.79) and 2.87-3.05) for N, P and K% of potato tubers, respectively during both seasons. While the lowest values with the control respectively during both seasons.

The different comparison between the mean values of N, P and K% of potato leaves and tubers as affected by the combination among different concentration of CPPU and NAA for 5 and 10 min soaking under investigation are presented in Table (5). Data clearly showed that; both soaking in CPPU and NAA significantly effect on N, P and K% of potato leaves and tubers. The highest mean values for the trait achieved with 10 mg $L^{-1}$ for each CPPU or NAA soaking for 10 min. The same trend was true during both seasons.

**Table 5. Averages values of nutrient contents (% d.w.) of potato leaves and tuber as affected by soaking in synthetic cytokinin (CPPU), auxin (NAA) and their combinations during the summer seasons of 2019/2020 and 2020/2021.**

| Treatments | | | Leaves | | | | | | Tubers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N% | | P% | | K% | | N% | | P% | | K% | |
| | | | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 | 2019/2020 | 2020/2021 |
| Soaking time | | | | | | | | | | | | | | |
| 5 min | | | 2.82b | 3.00b | 0.287b | 0.297b | 3.18b | 3.23b | 2.16b | 2.29b | 0.240a | 0.254b | 2.64b | 2.79b |
| 10 min | | | 2.88a | 3.07a | 0.293a | 0.303a | 3.24a | 3.29a | 2.21a | 2.36a | 0.245a | 0.260a | 2.69a | 2.86a |
| CPPU concentration mg $L^{-1}$ | | | | | | | | | | | | | | |
| 0 | | | 2.47c | 2.63c | 0.253c | 0.260c | 2.87c | 2.91c | 1.90c | 2.02c | 0.208c | 0.221c | 2.32c | 2.45c |
| 5 | | | 2.90b | 3.09b | 0.295b | 0.305b | 3.25b | 3.30b | 2.22b | 2.36b | 0.247b | 0.262b | 2.70b | 2.87b |
| 10 | | | 3.18a | 3.39a | 0.323a | 0.335a | 3.52a | 3.56a | 2.44a | 2.59a | 0.272a | 0.289a | 2.96a | 3.15a |
| NAA concentration mg $L^{-1}$ | | | | | | | | | | | | | | |
| 0 | | | 2.56c | 2.73c | 0.263c | 0.272c | 2.95c | 2.99c | 1.96c | 2.09c | 0.217c | 0.230c | 2.42c | 2.56c |
| 5 | | | 2.89b | 3.07b | 0.294b | 0.304b | 3.25b | 3.30b | 2.23b | 2.37b | 0.247b | 0.263b | 2.70b | 2.86b |
| 10 | | | 3.09a | 3.30a | 0.314a | 0.324a | 3.44a | 3.48a | 2.37a | 2.52a | 0.263a | 0.279a | 2.87a | 3.05a |
| Time | CPPU$^{-1}$ | NAA mg $L^{-1}$ | | | | | | | | | | | | |
| 5 min | 0 | 0 | 2.26n | 2.42k | 0.233n | 0.240l | 2.66o | 2.71m | 1.73l | 1.84k | 0.187l | 0.200m | 2.19l | 2.27m |
| | | 5 | 2.37m | 2.51j | 0.243m | 0.251k | 2.78n | 2.84l | 1.84k | 1.94j | 0.203k | 0.214l | 2.23kl | 2.35l |
| | | 10 | 2.69i | 2.86h | 0.275j | 0.284h | 3.07j | 3.12j | 2.06h | 2.19g | 0.226i | 0.240i | 2.49hi | 2.64hi |
| | 5 mg $L^{-1}$ | 0 | 2.52k | 2.70i | 0.262k | 0.270i | 2.93l | 2.97k | 1.94ij | 2.06hi | 0.213j | 0.226jk | 2.37j | 2.52j |
| | | 5 | 2.97f | 3.17e | 0.301g | 0.313e | 3.31g | 3.37fg | 2.27e | 2.41e | 0.255e | 0.271e | 2.77ef | 2.95ef |
| | | 10 | 3.11e | 3.32d | 0.315f | 0.326d | 3.41f | 3.45ef | 2.37d | 2.52d | 0.267d | 0.284d | 2.88cd | 3.07d |
| | 10 mg $L^{-1}$ | 0 | 2.82h | 3.02fg | 0.287i | 0.297g | 3.17i | 3.21hi | 2.16fg | 2.29f | 0.242g | 0.256g | 2.63g | 2.78g |
| | | 5 | 3.23c | 3.44c | 0.327d | 0.338c | 3.56d | 3.61cd | 2.48c | 2.63c | 0.277c | 0.293c | 3.01b | 3.19c |
| | | 10 | 3.36b | 3.58b | 0.343b | 0.355b | 3.71b | 3.76ab | 2.59ab | 2.74b | 0.287b | 0.305b | 3.16a | 3.35b |
| 10 min | 0 | 0 | 2.29n | 2.42k | 0.236n | 0.243l | 2.70o | 2.74m | 1.74l | 1.87k | 0.191l | 0.204m | 2.18l | 2.33lm |
| | | 5 | 2.43l | 2.59j | 0.251l | 0.260j | 2.84m | 2.88l | 1.90jk | 2.03i | 0.206k | 0.221k | 2.29k | 2.45k |
| | | 10 | 2.78h | 2.97g | 0.278j | 0.286h | 3.16i | 3.19ij | 2.10gh | 2.24fg | 0.234h | 0.249h | 2.54h | 2.69h |
| | 5 mg $L^{-1}$ | 0 | 2.58j | 2.75i | 0.267k | 0.276i | 2.98k | 3.03k | 1.99i | 2.11h | 0.218j | 0.231j | 2.43ij | 2.57ij |
| | | 5 | 3.02f | 3.23e | 0.305g | 0.316e | 3.37f | 3.41f | 2.34d | 2.48d | 0.259e | 0.275e | 2.82de | 2.99e |
| | | 10 | 3.17d | 3.37cd | 0.321e | 0.331cd | 3.48e | 3.54de | 2.44c | 2.59c | 0.268d | 0.284d | 2.93c | 3.11d |
| | 10 mg $L^{-1}$ | 0 | 2.88g | 3.09f | 0.294h | 0.305f | 3.24h | 3.29gh | 2.22ef | 2.36e | 0.248f | 0.264f | 2.71f | 2.88f |
| | | 5 | 3.31b | 3.52b | 0.337c | 0.349b | 3.65c | 3.69bc | 2.55b | 2.71b | 0.283b | 0.301b | 3.06b | 3.26c |
| | | 10 | 3.45a | 3.69a | 0.351a | 0.364a | 3.78a | 3.83a | 2.65a | 2.83a | 0.295a | 0.315a | 3.21a | 3.44a |

**Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.**

Generally increasing due to soaking in CPPU are true with Abd El-Hady *et al.* (2016) showed that soaking tubers per planting in BAP at the rate of 50 mg $L^{-1}$ and sprayed with the same concentration after planting increased significantly N, P and K% in leaves of potato. In addition, Brengi (2018) showed that synthetic cytokinins sprayed on leaves and tubers greatly enhanced N, P, K%. Also, Ahmed *et al.* (2021) observed that with increasing concentration of BA (25, 50 to 100 mg $L^{-1}$) significantly increased N, P and K% in leaves and tubers, the highest mean values were recorded at 100 mg $L^{-1}$ BA.

Positive effect of chlorophyll content and nutrition values in leaves as increasing NAA are connected with Abou El-Yazied and Mady (2011) showed that the concentration of naphthalene acetic acid obviously enhanced the concentrations of photosynthetic pigments, N, P, K% of tomato plant. Also, Jakhar *et al.* (2018) and Chanwala *et al.* (2019), applying NAA to sprouting broccoli significantly increased the amount of chlorophyll content. In addition, Ahmed *et al.* (2021) observed that foliar application by different concentration of NAA as auxin significantly affected in N, P and K% in leaves and tubers. The highest mean values were recorded at 100 mg $L^{-1}$ NAA.

## CONCLUSION

In general, the findings would advance our understanding of how to promote potato tuber yield and quality by soaking potato tubers for 5 and 10 minutes before planting in CPPU as synthetic cytokinin and NAA as auxin. Finally, tubers should soak in a solution containing 10 mg $L^{-1}$ CPPU and 10 mg $L^{-1}$ NAA for 10 minutes prior to planting in order to achieve the best development, high yield, and good quality without any risk from the potato tuber crop.

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## تأثير نمو المنفصلات النباتية لعيون درنات البطاطس استجابة بعض منظمات النمو


**عرفة على رجب العريني [1]، عبد الباسط عبد السميع الخربوطلي [2]، علي عدنان جبل [1] و محمود أحمد علي[1]**

**[1] قسم الإنتاج النباتي – كلية الزراعة سابا باشا – جامعة الإسكندرية**

**[2] قسم البساتين- كلية الزراعة والموارد الطبيعية – جامعة أسوان**

**[2] قسم البساتين- كلية الزراعة الصحراوية والبيئية – جامعة مطروح**



### الملخص

أجريت تجربتان حقليتان خلال الموسمين 2019-2020 و 2020-2021 في مزرعة خاصة تقع في منطقة أبو المطامير- محافظة البحيرة – مصر، تحت ظروف الحقل المفتوح لدراسة تأثير النقع في مستويات مختلفة من السيتوكينين (CPPU) و نفثالين أستيك أسيد (NAA) على النمو الخضري و المحصول و مكوناته و المحتوى الكيميائي و جودة الدرنات لنبات البطاطس صنف "كارا" للحصول على أعلى عائد اقتصادي من محصول البطاطس. تحتوى التجربة على وقت النقع (5 و 10 دقائق) كمعاملات رئيسية، 3 تركيزات من السيتوكينين (CPPU) بمعدل ( صفر، 5 ، 10 ملجم/لتر) كمعاملات منشقه اولي و3 تركيزات من النفثالين أستيك أسيد بمعدل (0، 5، 10 مجم/لتر) كمعاملات منشقة ثانية ، تم نقع الدرنات قبل الزراعة. وجد أن نقع الدرنات قبل الزراعة لمده 10 دقائق كان الأكثر فاعلية في الحصول على أعلى نمو خضري (طول النبات، عدد الأوراق و الفروع)، المحصول (متوسط وزن الدرنات و عددها و المحصول الكلى بالطن/فدان)، جوده الدرنات (محتوى النشا و المواد الصلبة الكلية و السكريات الكلية) و محتوى العناصر في الاوراق و الدرنات (النسبة المئوية للنيتروجين، الفوسفور و البوتاسيوم). بالإضافة الى ان النقع في 10 ملجم/لتر من CPPU و 10 ملجم/لتر من NAA لكل منها أدى الى زياده الصفات المذكورة. بصفه عامة يمكن التوصية بأن نقع الدرنات قبل الزراعة في 10 ملجم/لتر من CPPU و 10 ملجم/لتر من NAA لمده 10 دقائق قبل الزراعة أعطى أعلى إنتاجية إجمالية واقتصادية لنباتات البطاطس.