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Studies on Pre-harvest Spray of Alpha-NAA on Potato Crop in Relation to Enhance Potato (*Solanum tuberosum* L.) Tubers Storage

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ABSTRACT

The present investigation on a pre-harvest spray of alpha-1-naphthalene acetic acid (alpha-NAA) on potato crops in relation to improving the storage ability was undertaken in the Botany Department of Kurukshetra University, Kurukshetra, India on *Solanum tuberosum* cv. 'Kufri Chandermukhi'. Sprout initiation was observed in tubers on the 20th day, with 4.0 x 10^{-4} M application of alpha-NAA during storage. In control, it was prominently noticed on the first observation made on the 10th day (0.8 mm), whereas in the treated one, it was very small. These treatments were able to check the percentage of sprouting. Rottage was observed after the 40th day of storage. The decline in starch content was less in the treatment group than in the control group up to the 20 days, but a reverse trend was witnessed after that compared with initial values. The starch contents were significantly higher in treated tubers than untreated in most stages. After 40 days, per cent cumulative physiological weight loss values were 9.20, 9.62, and 10.33% in 4.0 x 10^{-4} M alpha-NAA, 5.5 x 10^{-4} M alpha-NAA, and control, respectively.

Keywords: Alpha-NAA, pre-harvest spray, potato, sprouting, storage

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is a stem tuber crop belonging to the family Solanaceae. It is a unique crop that can supplement mankind's food needs substantially (Scott et al., 2019). In world history, potatoes have been a well-known food commodity, and whenever there has been an insufficiency of food grains for people, the potato has come to rescue life (Neeraj et al., 2019). It produces well-balanced protein content and additional calories/unit area and is produced in less per unit time than other cereal crops. Therefore, it is the most suitable non-traditional crop to ward off hunger. Potato tubers are important for human food and nutrition, employment, and income in Africa, Asia, and Latin America, which is self-apparent from the steady expansion in the area and production of tubers in developing countries (Devaux et al., 2020).

Out of the total dry matter accumulation in potatoes, about 80% is starch, which mainly contributes to the calorific value of the potato. Sugars occur in varying quantities, being very low at harvest, and could increase to a very high level at the end of the storage period (Neeraj et al., 2019). Potato proteins are better than cereal proteins because of their balanced amino acid composition, equivalent to some proteins of animal origin (Kapoor et al., 1975). Among the various vitamins in potatoes, vitamin C is the largest.

Asian farmers produce potatoes during the *rabi* season and store them for hot summers. The coming sowing season depends upon storage conditions to guarantee a sufficient and balanced supply of this fragile product (seed and table potatoes) (Lu et al., 2012). The potato tubers' storage is not only important from the marketing point of view, but it is also required for their utilization as seed potatoes for crop cultivation. In India, refrigerated storage facilities are expensive, insufficient, and unevenly distributed; therefore, during surplus availability of potato tubers in the vegetable market, growers get big financial losses as well as waste of commodity.

According to Kaguongo et al. (2014), the post-harvest tuber losses at farmer's fields, vegetable markets, and processing facilities are estimated at 12.8, 24.4, and 25.0%, respectively. Sprouting is mainly responsible for weight loss as well as degradation in the marketable quality of potato tubers and seed tubers (Suttle, 2003). Problems related to storage have been identified as the major constraints in achieving a further increase in the production of potatoes in India (Neeraj et al., 2019). The potato seed industries rely mainly on stored tubers. Losses in stored potatoes are due to sprouting, shrinkage, and rotting. Therefore, adequate storage infrastructure is necessary to prevent potato rot, sprouting, and physiological weight loss. The time of onset of sprouting is determined by the length of the dormancy period of the tubers. Shrinkage occurs due to the loss of water from tubers to air in stores along a water vapour pressure gradient and the consumption of respiratory substances. The main purpose of potato storage is to maintain tubers in their most edible and saleable condition.

Not all farmers have access to a refrigerated cold storage facility in nearby areas. Due to this lack of facility, tubers sprout during long-duration storage (Foukaraki et al., 2016), and this problem may be solved with the help of sprout inhibitors and growth regulators. Therefore, the present study was carried out on a pre-harvest spray of alpha-NAA on a potato crop to improve its storage ability.

MATERIALS AND METHODS

Experimental Crop and Application of Alpha-NAA

'Kufri Chandermukhi' was selected as a plant material for the present investigation, undertaken in the Botany Department of Kurukshetra University, Kurukshetra, *Solanum tuberosum* cv. seed tubers were obtained from Central Potato Research Institute, Substation Modipuram (Utter Pradesh). The experimental crop was grown in nine beds in the University Botanical Garden, Kurukshetra University, Kurukshetra (N 29° 57' 26.3124", E 76° 48' 59.742"). The area of each experimental bed was 1 x 3 m^2.

Three beds were selected for applying each alpha-NAA concentration (4.0 x 10^{-4} and 5.5 x 10^{-4} M, ChemSupply, Australia) as pre-harvest treatments six weeks before harvesting. Three beds were sprayed with distilled water and maintained as controls. No rainfall was received after the application of treatments until the harvesting of tubers, although arrangements were made for rain in this area.

Tubers Storage and Observations

The crops were lifted when haulms died down naturally. Harvesting operations were done in dry weather with hand hoes. After harvesting, potatoes were spread on the floor at room temperature for five days.

Potato tubers from treated and control plants were collected separately, kept in cold storage (1–3°C with 90%RH) for 120 days, and then brought to the laboratory for physiological and biochemical analysis at room temperature 30±2°C.

Physiological Analysis

After 120 days of cold storage, periodic observations up to 40 days at room temperature were made for percentage crude protein weight loss (CPWL), sprouting behaviour and percentage rottage after a regular interval of 10 days using 70–90 g weight category of potato tubers.

Biochemical Analysis

Biochemical analysis was carried out on starch, sugars (reducing, non-reducing, and total), ascorbic acid, and protein. The specific enzymatic activity of alpha-amylase and peroxidase was also determined (Association of Official Analytical Chemist [AOAC], 1990).

RESULTS AND DISCUSSION

Sprouting and Spoilage

Sprouting behaviour results presented in Table 1 reveals that pre-harvest alpha-NAA treatment had slightly delayed the initiation of sprouts. It also greatly reduced

the number of sprouts per tuber. The number of sprouts was brought down from 3.70 to 1.41, 4.76 to 2.11, and 7.21 to 5.01 per tuber by the lower concentration of this growth regulator (4.0×10^{-4} M) on the 20th, 30th, and 40th days, respectively. Sprout initiation was observed on the 20th day in tubers, which had 4.0×10^{-4} M application of alpha-NAA. In control, it was prominently noticed on the very first observation made on the 10th day (0.8 mm), whereas in the treated one, it was very small. These treatments were able to check the percentage of sprouting. Rottage was observed after the 40th day of storage.

Per cent cumulative physiological weight loss (%CPWL) data reveals that alpha-NAA treatment significantly influenced the %CPWL of tubers during room-temperature storage. After 40 days, values were 9.20, 9.62, and 10.33% in 4.0×10^{-4} M alpha-NAA, 5.5×10^{-4} M alpha-NAA, and control, respectively.

The significant results and interpretation of the present experimentation concurrs with those of previous research workers (Birbal et al., 2009). They found a decline in the total and physiological weight reduction in the tubers using growth regulators, i.e., gibberellic acid and auxins (NAA and indole-3-butanoic acid [IBA]), applied to the foliage. Additionally, the reduction in total weight loss resulting from applying gibberellins may be attributed to decreased activity of enzymes responsible for the hydrolysis of cell walls, as Miceli et al. (2019) observed.

These findings strongly agree with the previous research by Birbal et al. (2009), who also reported a reduction in tuber rottage with gibberellic acid application compared to the control. The reduction in sprouting with pre-application of gibberellic acid may develop the thicker cuticle (thick tuber skin) with more dry matter accumulation in the potato tubers. These structural modifications are apparent in reducing post-harvest losses coupled with the sprouting feature (Miceli et al., 2019). However, Nyankanga et al. (2018) observed that applying pre-ethrel could augment the sprouting percentage in potato tubers during storage.

According to Wang et al. (2009), the increase in the potato tubers dry matter content is accompanied with the application of growth regulation treatments. Likewise, Alexopoulos et al. (2006) also studied the effect of gibberellic acid on potato crop growth and development, and they reported that the time of spray of gibberellic acid is also important; it imparts the high accumulation of dry matter in haulms, leaves, and especially in below ground part (potato tubers) and more deposition of dry matter related to higher carbohydrate accumulation and sugars.

Changes in Biochemical Parameters

The protein content of tubers also shows a decreasing trend with an increase in the storage period (Table 2). Higher values were recorded in the cortex than in the pith. The protein value was lower in treated tubers than in control tubers. A maximum decrease in protein content was recorded during 30-40 days in untreated and treated tubers.

Ascorbic acid results based on both concentrations were able to reduce the loss of ascorbic acid, thus reflecting a gradual decrease during storage in all the tubers. The increment in ascorbic acid in the cortex of the tubers treated with 4.0 x 10^{-4} M alpha-NAA was significant compared with the control on the 20th, 30th, and 40th days. The amount was much higher in the pith than in the cortex.

Starch values initially were 57.48-58.41, 65.49-68.23, 68.13-68.83 mg/100 mg on a dry weight basis in control, 5.5 x 10^{-4} and 4.0 x 10^{-4} M alpha-NAA treated tubers, respectively, in pith-cortex regions. Significant decline was noticed in room temperature storage in treated and control tubers. The decline was less in the treatment group than in the control group up to the 20 days, but a reverse trend was witnessed after

Table 1
Effect of pre-harvesting alpha-naphthalene acetic acid treatment on sprouting, rotting, and water losses of potatoes at room temperature storage (30±2°C)

Storage days	Treatments	Per cent sprouting	Number of sprout/ tuber	Length of longest sprout (mm)	Range of sprout length (mm)	Per cent rotting	Per cent cumulative physiological weight loss
10	Control	13.50	1.21	0.80	J - 0.80	-	1.50
	4.0 x 10^{-4} M NAA	-	-	-	-	-	1.14
	5.5 x 10^{-4} M NAA	-	-	-	J - 0.20	-	1.19
20	Control	28.30	3.70	5.00	J - 3.00	-	3.48
	4.0 x 10^{-4} M NAA	15.00	1.41	2.00	J - 1.43	-	3.08
	5.5 x 10^{-4} M NAA	18.20	1.81	2.90	J - 2.10	-	3.36
30	Control	37.30	4.76	8.00	J - 8.00	-	7.07
	4.0 x 10^{-4} M NAA	30.10	2.11	5.42	J - 5.42	-	6.02
	5.5 x 10^{-4} M NAA	33.20	2.45	7.20	J - 7.20	-	6.44
40	Control	52.10	7.21	13.20	J - 13.20	50	10.33
	4.0 x 10^{-4} M NAA	48.80	5.01	10.00	J - 10.00	10	9.20
	5.5 x 10^{-4} M NAA	49.20	5.21	11.40	J - 11.40	15	9.62

Note. J = Just initiation; NAA = Naphthalene acetic acid

that when compared with the initial values. The starch contents were significantly higher in treated tubers than untreated in most stages.

Sugar content data showed increased total sugars with prolonged storage at room temperature. The pith region exhibited a slightly higher sugar content than the cortex. As the storage period advanced, the increase in total sugars was greater in treated tubers than in the control when the differences were calculated on the 40th day in cortex-pith from initial values.

The increase in total sugars was mainly due to reduced and non-reducing sugars in treated and untreated. The results showed an increase in reducing sugars with an increase in storage days. From the start, from zero-day onwards, there was no reduction in sugars; however, there was a decline with the increase in storage period. The pith region has a lower value than the cortex. The increase was significant from control to treated tubers on the 20th and 30th days. Potato tubers' total soluble solids (TSS) content is chiefly total sugars dominated and a small fraction of soluble protein, amino acids, and several other biological compounds (Bexiga et al., 2017).

The study implies that the spray of growth regulators on potato crops did not impart any considerable effect on the potato tubers' TSS content during the storage period. It may be because TSS content mainly depends on the inherent potential of variety, agronomic interventions, fertilizer application, and metabolic or functional status; hence, it was not inclined by growth regulators application. These results align with the earlier results of Sarkaria and Chinna (2021); they also observed that the TSS content in tubers was not significantly enhanced by using growth regulators application.

Changes in Specific Enzyme Activities

In the present study, the specific activity of alpha-amylase was significantly increased during storage in treated and control tubers for up to 30 days (Table 2). However, activity was lower in treated tubers than control ones; after 30 days, it registered a further decline in the case of 4.0 x 10^{-4} M alpha-NAA-treated ones. Pith samples exhibited higher activity than the cortex.

The specific activity of peroxidase was comparatively lower in treated than untreated tubers. The specific activity of peroxidase enzyme increased up to 20 days in untreated tubers, after which a gradual decline was noticed. Treated tubers registered a sharp fall at ten days, followed by further decline up to 40 days. The difference between the two concentrations of alpha-NAA was less marked. Peroxidase activity was comparatively lower in treated than untreated tubers.

The increase in total phenol content in potato tubers with applying gibberellic acid may be accredited to a resultant increase in the antioxidant activity associated with phenolic compounds, as Gilani et al. (2021) reported. The potato seed tubers, which are recently harvested, contain about 70% water and are more vulnerable to rot, blemish diseases, and galls while being stored under

Table 2
Effect of pre-harvesting alpha-naphthalene acetic acid treatment on biochemical changes of potato tubers at room temperature storage (30±2°C)

Treatment	Tuber part	0 day	10th day	20th day	30th day	40th day
Protein changes (mg/100 mg dry weight)						
Control	Pith	6.48±0.28	5.18±0.02	4.55±0.08	4.25±0.18	2.97+0.19
	Cortex	6.85±0.30	5.89±0.20	5.16±0.02	4.89±0.18	3.82±0.10
4.0 x 10^{-4} M NAA	Pith	5.87±0.26	4.81±0.04	4.10±0.18	3.57±0.04	2.51±0.02
	Cortex	6.16±0.27	5.38±0.01	4.51±0.01	3.92±0.01	3.32±0.09
5.5 x 10^{-4} M NAA	Pith	6.19±0.04	4.93±0.10	4.33±0.02	3.92±0.02	2.73±0.19
	Cortex	6.56±0.04	5.63±0.20	4.94±0.17	4.55±0.09	3.73±0.10
Ascorbic acid changes (mg/100 mg dry weight)						
Control	Pith	54.45±0.03	52.71±0.02	48.45±0.03	45.85±0.04	39.79±0.03
	Cortex	51.45±0.02	49.67±0.02	45.18±0.01	42.95±0.02	37.54±0.03
4.0 x 10^{-4} M NAA	Pith	57.14±0.02	53.19±0.02	49.54±0.02	47.35±0.03	41.85±0.03
	Cortex	53.65±0.04	50.16±0.03	47.81±0.04	45.25±0.02	40.39±0.04
5.5 x 10^{-4} M NAA	Pith	55.67±0.03	54.81±0.01	49.52±0.05	47.38±0.03	42.39±0.03
	Cortex	52.56±0.04	51.76±0.02	47.81±0.01	44.52±0.01	40.18±0.05
Starch changes (mg/100 mg dry weight)						
Control	Pith	57.48±0.33	43.83±0.56	43.61±0.31	39.33±0.91	37.52±0.63
	Cortex	58.41±0.85	50.47±0.83	43.47±0.51	42.83±0.13	41.61±0.66
4.0 x 10^{-4} M NAA	Pith	68.13±0.29	62.61±0.25	52.40±0.24	42.66±0.31	37.83±0.13
	Cortex	68.82±0.09	65.61±0.50	53.48±0.20	45.55±0.23	38.92±0.22
5.5 x 10^{-4} M NAA	Pith	65.49±0.01	57.16±0.59	53.40±0.48	42.65±0.41	35.88±0.39
	Cortex	68.23±0.11	57.40±0.50	56.03±0.26	46.55±0.80	37.22±0.22
Total sugars (mg/100 mg dry weight)						
Control	Pith	6.20±0.01	6.37±0.01	7.10±0.02	7.45±0.02	8.20±0.01
	Cortex	6.03±0.02	6.23±0.01	7.06±0.03	7.25±0.01	8.05±0.01
4.0 x 10^{-4} M NAA	Pith	6.49±0.01	7.14±0.01	8.16±0.01	9.15±0.28	10.27±0.01
	Cortex	6.37±0.02	7.04±0.02	8.04±0.00	9.24±0.03	10.20±0.01
5.5 x 10^{-4} M NAA	Pith	6.48±0.01	6.85±0.03	7.37±0.01	8.22±0.01	9.32±0.01
	Cortex	6.27±0.01	6.73±0.01	7.44±0.02	8.11±0.01	9.27±0.01
Reducing sugars (mg/100 mg dry weight)						
Control	Pith	3.07±0.03	3.42±0.06	4.99±0.19	5.39±0.13	6.32±0.09
	Cortex	2.74±0.01	3.16±0.07	4.49±0.11	4.73±0.13	6.04±0.13
4.0 x 10^{-4} M NAA	Pith	3.37±0.08	4.08±0.06	5.27±0.07	6.16±0.02	8.14±0.04
	Cortex	3.19±0.03	3.46±0.29	5.02±0.10	5.85±0.12	7.59±0.12
5.5 x 10^{-4} M NAA	Pith	3.17±0.05	3.24±0.01	5.11±0.09	5.70±0.13	7.24±0.13
	Cortex	2.89±0.04	3.62±0.08	4.72±0.12	5.55±0.11	7.09±0.13
Non-reducing sugars (mg/100 mg dry weight)						
Control	Pith	3.13±0.06	2.95±0.05	2.11±0.01	2.06±0.02	1.88±0.04
	Cortex	3.29±0.08	3.07±0.10	2.57±0.03	2.52±0.02	2.01±0.01
4.0 x 10^{-4} M NAA	Pith	3.12±0.10	3.06±0.07	2.89±0.12	2.99±0.04	2.13±0.20
	Cortex	3.18±0.03	3.58±0.03	3.02±0.08	3.39±0.06	2.61±0.01
5.5 x 10^{-4} M NAA	Pith	3.31±0.05	3.61±0.04	2.26±0.05	2.52±0.01	2.08±0.03
	Cortex	3.38±0.07	3.11±0.08	2.72±0.05	2.56±0.01	2.18±0.04

Table 2 *(Continue)*

Treatment	Tuber part	0 day	10th day	20th day	30th day	40th day
The specific activity of alpha-amylase (on a per mg protein basis)						
Control	Pith	0.43±0.01	0.49±0.01	0.59±0.01	0.61±0.01	0.64±0.03
	Cortex	0.42±0.01	0.48±0.01	0.54±0.01	0.60±0.01	0.65±0.01
4.0 x 10^{-4} M NAA	Pith	0.36±0.01	0.40±0.01	0.48±0.01	0.49±0.01	0.45±0.01
	Cortex	0.33±0.01	0.40±0.01	0.41±0.01	0.44±0.01	0.44±0.01
5.5 x 10^{-4} M NAA	Pith	0.37±0.01	0.39±0.01	0.48±0.01	0.41±0.01	0.45±0.01
	Cortex	0.34±0.01	0.39±0.01	0.42±0.01	0.45±0.01	0.44±0.01
Specific activity of peroxidase (on per mg protein basis)						
Control	Pith	0.31±0.01	0.29±0.00	0.32±0.00	0.15±0.01	0.11±0.01
	Cortex	0.29±0.01	0.28±0.01	0.38±0.01	0.12±0.01	0.08±0.01
4.0 x 10^{-4} M NAA	Pith	0.21±0.01	0.18±0.01	0.10±0.01	0.13±0.01	0.08±0.01
	Cortex	0.25±0.01	0.09±0.01	0.08±0.01	0.08±0.01	0.05±0.01
5.5x10^{-4}M NAA	Pith	0.28±0.01	0.12±0.01	0.10±0.01	0.13±0.01	0.09±0.01
	Cortex	0.27±0.01	0.08±0.01	0.09±0.01	0.10±0.01	0.05±0.00

Note. NAA = Naphthalene acetic acid

ambient conditions. Gilani et al. (2021) also stated that gibberellic acid stimulates pathogen defence-related enzymes, e.g., polyphenol oxidase and peroxidase, and elevates the phenolic substance, which imparts systemic resistance against pathogens.

In the present study, foliar spray of alpha-NAA six weeks before harvest was found effective and reduced per cent sprouting at concentrations of 4.0 x 10^{-4} and 5.5 x 10^{-4} M alpha-NAA when potatoes were maintained at room temperature after 120 days of initial cold storage. Besides causing a delay in sprout initiation, this growth substance also reduced sprout growth and the number of sprouts per tuber. Birbal et al. (2009) reported that NAA at a concentration of 60–100 ppm had delayed the tubers sprouting and suppressed the growth of sprouts in the variety Dargheeling Red Round. NAA applied at 120 ppm had only a small influence in delaying the sprouting of tubers.

More recently, Elsherbiny et al. (2023) stated the negative association between phenolic compounds and potato dry rot diseases. The earlier findings of Sourati et al. (2022) revealed that the IBAs performed better than NAAs among auxins to improve the potato tubers' quality. Likewise, Chandra and Mondy (1981) also observed that IBA and NAA affected the phenol and dry matter biochemical composition and quality of potato tubers as plant hormones alter growth and development. Kondhare et al. (2021) observed that the pre-harvest application of auxins significantly improved the quality attributes of potatoes. Busse and Bethke (2020) also advocated the foliar application of auxins as they enhanced the antioxidants and qualitative attributes. Clarke et al. (2020) also observed that low-dose auxin foliar application

reduced potato diseases, and they further stated that the auxin foliar application enhanced potato tubers' weight significantly compared to the control (no spray).

CONCLUSION

The sprouting of potato tubers may be reduced by the foliar spray of 4.0 x 10^{-4} M alpha-NAA on potato crops six weeks before harvest. Moreover, alpha-NAA foliar application significantly enhanced the weight of potato tubers and reduced peroxidase activity.

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REFERENCES

Alexopoulos, A. A., Akoumianakis, K. A., & Passam, H. C. (2006). The effect of the time and mode of application of gibberellic acid on the growth and yield of potato plant derived from true potato seed. *Journal of the Science of Food and Agriculture*, *86*(13), 2189-2195. https://doi.org/10.1002/jsfa.2595

Association of Official Analytical Chemist. (1990). *Official methods of analysis* (15th ed.). AOAC.

Bexiga, F., Rodrigues, D., Guerra, R., Brázio, A., Balegas, T., Cavaco, A. M., Antunes, M. D., & de Oliveira J. V. (2017). A TSS classification study of 'Rocha' pear (*Pyrus communis* L.) based on non-invasive visible/near infra-red reflectance spectra. *Postharvest Biology and Technology*, *132*, 23-30. https://doi.org/10.1016/j.postharvbio.2017.05.014

Birbal., Singh, R. K., Kumar, V., & Kushwah, V. S. (2009). Effect of foliar application of plant growth regulators on growth, yield, and post-harvest losses of potato (*Solanum tuberosum*). *Indian Journal of Agricultural Sciences*, *79*(9), 684-686.

Busse, J. S., & Bethke, P. C. (2020). Impact of 2,4-D and potato (*Solanum tuberosum* L.) tuber age on anthocyanin content of skin and phellem anatomy of Red Norland. *American Journal of Potato Research*, *97*, 102-110. https://doi.org/10.1007/s12230-019-09760-5

Chandra, S., & Mondy, N. I. (1981). Effect of foliar application of auxin on the quality of potatoes. *Journal of Food Science*, *46*(6), 1870-1873. https://doi.org/10.1111/j.1365-2621.1981.tb04507.x

Clarke, C. R., Tegg, R. S., Thompson, H. K., Frederick, C., Haynes, K. G., Kramer, M., & Wilson, C. R. (2020). Low-dose foliar treatments of the auxin analog 2,4-D reduce potato common scab and powdery scab for multiple potato cultivars and enhance root development. *Crop Protection*, *136*, 105208. https://doi.org/10.1016/j.cropro.2020.105208

Devaux, A., Goffart, J.-P., Petsakos, A., Kromann, P., Gatto, M., Okello, J., Suarez, V., & Hareau, G. (2020). Global food security, contributions from sustainable potato agri-food systems. In H. Campos & O. Ortiz (Eds.), *The potato crop* (pp. 3-35). Springer. https://doi.org/10.1007/978-3-030-28683-5_1

Elsherbiny, E. A., Dawood, D. H., Elsebai, M. F., Mira, A., & Taher, M. A. (2023). Control of dry rot and resistance induction in potato tubers against *Fusarium sambucinum* using red onion peel extract. *Postharvest Biology and Technology*, *195*, 112119. https://doi.org/10.1016/j.postharvbio.2022.112119

Foukaraki, S. G., Cools, K., Chope, G. A., & Terry, L. A. (2016). Impact of ethylene and 1-MCP on sprouting and sugar accumulation in stored potatoes. *Postharvest Biology and Technology*, *114*, 95-103. https://doi.org/10.1016/j.postharvbio.2015.11.013

Gilani, S. A. Q., Basit, A., Sajid, M., Shah, S. T., Ullah, I., & Mohamed, H. I. (2021). Gibberellic acid and boron enhance antioxidant activity, phenolic content and yield quality in *Pyrus communis* L. *Gesunde Pflanzen*, *73*, 395-406. https://doi.org/10.1007/s10343-021-00555-5

Kaguongo, W., Maingi, G., & Giencke, S. (2014). *Post-harvest losses in potato value chains in Kenya: Analysis and recommendations for reduction strategies*. Deutsche Gesellschaft für Internationale Zusammenarbeit, German Food Partnership, and Sector Network Rural Development. https://doi.org/10.13140/2.1.3761.3764

Kapoor, A. C., Desborough, S. L., & Li, P. H. (1975). Potato tuber proteins and their nutritional quality. *Potato Research*, *18*, 469-478. https://doi.org/10.1007/BF02361913

Kondhare, K. R., Patil, A. B., & Giri, A. P. (2021). Auxin: An emerging regulator of tuber and storage development. *Plant Science*, *306*, 110854. https://doi.org/10.1016/j.plantsci.2021.110854

Lu, Z.-H., Donner, E., Yadav, R. Y., & Liu, Q. (2012). Impact of γ-irradiation, CIPC treatment, and storage conditions on physicochemical and nutritional properties of potato starches. *Food Chemistry*, *133*(4), 1188-1195. https://doi.org/10.1016/j.foodchem.2011.07.028

Miceli, A., Moncada, A., Sabatino, L., & Vetrano, F. (2019). Effect of gibberellic acid on growth, yield, and quality of leaf lettuce and rocket grown in a floating system. *Agronomy Journal*, *9*(7), 382. https://doi.org/10.3390/agronomy9070382

Neeraj., Siddiqui, S., & Dalal, N. (2019). Influence of sprout inhibiting treatments and packaging methods on storage performance of Kufri Chipsona 4 potato. *Indian Journal of Horticulture*, *76*(4), 728-734. https://doi.org/10.5958/0974-0112.2019.00115.4

Nyankanga, R. O., Murigi, W. W., Shibario, S. I., Olanya, O. M., & Larkin, R. P. (2018). Effects of foliar and tuber sprout suppressants on storage of ware potatoes under tropical conditions. *American Journal of Potato Research*, *95*, 539-548. https://doi.org/10.1007/s12230-018-9662-0

Sarkaria, A. S., & Chinna, G. S. (2021). Effect of gibberellic acid and potassium nutrition on yield and potassium uptake of potato. *Agriculture Research Journal*, 58(1), 146-149. https://doi.org/10.5958/2395-146X.2021.00022.3

Scott, G. J., Petsakos, A., & Juarez, H. (2019). Climate change, food security, and future scenarios for potato production in India to 2030. *Food Security*, *11*, 43-56. https://doi.org/10.1007/s12571-019-00897-z

Sourati, R., Sharifi, P., Poorghasemi, M., Vieira, E. A., Seidavi, A., Anjum, N. A., Sehar, Z., & Sofo, A. (2022). Effects of naphthaleneacetic acid, indole-3-butyric acid, and zinc sulfate on the rooting and growth of mulberry cuttings. *International Journal of Plant Biology*, *13*(3), 245-256. https://doi.org/10.3390/ijpb13030021

Suttle, J. C. (2003). Auxin-induced sprout growth inhibition: Role of endogenous ethylene. *American Journal of Potato Research*, *80*, 303-309. https://doi.org/10.1007/BF02854314

Wang, H., Li, H., Liu, F., & Xiao, L. (2009). Chlorocholine chloride application effects on photosynthetic capacity and photoassimilates partitioning in potato (*Solanum tuberosum* L.). *Scientia Horticulturae*, *119*(2), 113-116.https://doi.org/10.1016/j.scienta.2008.07.019