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Effects of Climate Variation on Spring Potato Growth, Yield, and Quality in South Korea

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Abstract: In South Korea, spring potatoes account for over 60% of total potato production, but global warming and anomalous weather events may impact their growth and yield. This study examined potato cultivation practices across 12 locations with varying climates, analyzing meteorological factors, soil properties, and potato composition to identify stable cultivation areas. A survey of 45 farms revealed earlier planting dates in G3 regions compared to G2 and G1. Regions were classified into three groups (G1, G2, and G3) based on climatic conditions, with G1 representing the most temperate regions, G2 indicating regions with moderate climates, and G3 including areas with the warmest climates. The Superior variety was predominately cultivated in average areas of 1.4 ha. Yields ranged from 22,500 to 35,000 kg/ha, with G2 regions producing the highest yields. During tuber formation, plant height in G2 and G3 was greater than in G1, but no differences were noted at harvest. Planting times correlated with higher February and March temperatures, which were highest in G3. Soil properties were suitable across all regions, with minor variations. Ash and crude fat content were highest in G1 crops, while ascorbate and glutathione levels were highest in G3. No significant differences were found in total phenol and flavonoid content, though G2 and G3 showed higher antioxidant activity. Similar weather during the main growth period (April–June) minimized regional differences in growth, yield, and quality, but ongoing monitoring is recommended as climate change progresses. Overall, this study provides insights into how climatic conditions affect potato cultivation in South Korea and emphasizes the importance of adapting farming practices to ensure stable yields under changing climate conditions.

Keywords: potato; cultivation practices; meteorological factors; growth characteristics; yield; soil chemical properties; secondary metabolites

Academic Editor: Carlo Leifert

Received: 18 December 2024
Revised: 3 January 2025
Accepted: 9 January 2025
Published: 9 January 2025

Citation: Park, H.H.; Ei, E.; Kuk, Y.I. Effects of Climate Variation on Spring Potato Growth, Yield, and Quality in South Korea. *Agronomy* **2025**, *15*, 149. https://doi.org/10.3390/agronomy15010149

1. Introduction

Climate change has emerged as one of the most significant issues over the past two decades. The primary cause of this climate change is known to be the phenomenon of increasing atmospheric temperature due to the rise in carbon dioxide (CO_2) concentration in the atmosphere [1,2]. Consequently, the global average temperature is predicted to increase by 2.4–6.4 °C by the end of this century [3]. Climate change not only increases the frequency of abiotic stress factors such as typhoons, droughts, floods, and heavy rainfall, but also has severe impacts on ecosystems, food production, and human health [3]. Agriculture, in particular, is highly sensitive to climate change, and it is anticipated that these extreme weather conditions will negatively affect crop community structure and inorganic nutrients, leading to decreased productivity [4]. Furthermore, climate change in the agricultural sector is expected to cause soil erosion and water scarcity, deteriorating crop cultivation environments, altering suitable cultivation areas, and raising concerns about the emergence of new pests and weeds [5–7].

The evaluation of temperature can adversely affect crops' physiological processes, including photosynthesis, respiration, and assimilate distribution, potentially leading to reduced yields [8,9]. Climate change impacts vary across regions and conditions. For instance, warmer conditions may enhance crop yields in areas with cooler springs and summers. Conversely, in regions with warmer climates, temperature increases could result in yield reductions [10]. Moreover, rising temperatures may shorten crop growth and maturation periods [11]. Numerous studies have extensively documented the negative effects of climate change on crop productivity [12–18]. Given that agricultural practitioners cannot directly alter climatic conditions, it is crucial to develop adaptation strategies that mitigate the adverse impacts of climate change by adjusting certain cultivation management factors such as soil, water resources, and cultivar selection [19,20].

Solanum tuberosum L., commonly known as the potato, is a member of the Solanaceae family originating from the Andean region. It ranks among the world's four major food crops alongside maize, rice, and wheat, and is cultivated in numerous countries [21–24]. The potato's popularity as a staple food is attributed to its long shelf life, palatability, and satiating properties. Due to its high water content, the potato is categorized as a low-calorie food compared to cereals. It is nutritionally valuable, being rich in vitamins such as C, B1, B2, and niacin. Furthermore, the potato's abundance of protein, minerals like potassium and phosphorus, and dietary fiber contribute to its excellent health-promoting characteristics [24–28].

In the Republic of Korea, potato cultivation is divided into four seasons: spring (March–June), summer (April–September), autumn (August–November), and winter greenhouse cultivation (December-April of the following year), with an annual production of approximately 590,000 tons [29]. Spring potato cultivation, accounting for over 60% of national potato production, is the predominant cultivation pattern. In lowland areas across the country, planting occurs from late February to late March, with harvesting taking place from late May to late June [30]. However, the increasing probability of abnormal weather events due to global warming suggests a high likelihood of changes in the growth response and productivity of spring potatoes [23].

Potatoes exhibit significant variability in growth and quality across different cultivation regions, even within the same variety, demonstrating their high sensitivity to meteorological factors [31]. The optimal conditions for above-ground and below-ground tuber growth differ [32]. While the ideal temperature range for above-ground growth is 20–25 °C, tuber formation and optimal growth occur at 15–20 °C [33]. Potato yield increases under low-temperature and short-day conditions, with a photoperiod of approximately 12 h being most suitable [34]. Higher solar radiation promotes tuber enlargement [35].

Climate change-induced water scarcity or temperature elevation may lead to decreased potato yields [36]. Potato cultivation requires 400–800 mm of precipitation, varying based on meteorological variables and other factors [12,37]. Moisture deficits exceeding 60–65% during potato cultivation can induce drought, reducing growth rates, while excessive water may cause tuber rot [37,38]. Beyond abiotic factors, biotic elements such as pests, nematodes, and pathogens also influence potato yields [37,39]. Conversely, atmospheric CO_2 increase, a driver of global warming, enhances net assimilation per unit leaf area and unit time of dry matter [40]. Notably, CO_2 elevation has been associated with a 27–49% increase in dry matter and yield [41–44].

The concept of safe cultivation zones for crops refers to areas with comparable meteorological conditions that do not significantly impact crop growth and yield [45]. The most reliable method for determining these zones involves cultivating crops in various regions and assessing growth and yield reductions [46]. However, this approach is resource-intensive and time-consuming. Consequently, a more prevalent method entails examining the meteorological conditions of current suitable cultivation areas and identifying regions with similar climatic characteristics as safe cultivation zones. This method, too, has limitations, as crop growth and yield are influenced by both meteorological and abiotic factors. Crop models utilizing future climate change scenarios (RCP, SSP, CMIP, etc.) are extensively employed to analyze the effects of climate change on crop yields and management practices [47–53]. While these models can aid in developing alternative adaptation strategies to mitigate climate change impacts, numerous variables must be considered when determining actual suitable cultivation areas.

Climate change may alter the regions suitable for potato cultivation. Particularly, if warming trends persist, summer temperatures in current cultivation areas may become excessively high, potentially shifting suitable zones to highland areas or more northern regions. This study investigated potato growth during the elongation period (April) and yield differences at harvest (June) by planting potatoes in 12 locations across three groups with distinct climate distributions. Additionally, meteorological factors and soil chemical properties were examined among these groups. At harvest, analyses of potato general components, vitamin C, and secondary metabolites were conducted to identify stable cultivation areas for potatoes.

2. Materials and Methods

2.1. Survey of Potato Cultivation Pratices in Various Growing Regions

In 2024, a comprehensive survey of potato cultivation practices was conducted across multiple regions. The study encompassed 20 farms in four areas of Gangwon and Gyeonggi (G1), 13 farms in three areas of Chungbuk, Chungnam, and Gyeongbuk (G2), and 12 farms in three areas of Jeonbuk and Jeonnam (G3) each group having different climate distributions, including temperature. Data collection involved both on-site visits and telephone interviews. The survey gathered information on planting dates, cultivation areas, potato varieties, usage rates of certified seed potatoes, and yield per ha.

2.2. Potato Growth and Yield Variations in Climatically Diverse Cultivation Sites

To investigate the impact of climatic diversity on potato growth and yield, the study sites were categorized into three groups, with four locations per group, totaling 12 experimental sites. Each group had distinct climate distributions, including variations in temperature. Certified seed potatoes of the *Superior* variety were planted in the following locations: G1 group: Yeoncheon, Pocheon, Chuncheon, Hongcheon; G2 group: Goesan, Sangju, Gumi, Seocheon; G3 group: Namwon, Jinju, Boseong, Jangheung. The geographical coordinates of these sites were plotted on a map (Figure 1). This study was carried out in one growing season in 2024. Soil pH, EC, and other chemical properties were presented in Section 3. Investigation parameters included the planting dates, seeding rates, cultivation areas, plant spacing, and harvest dates for each site. Other cultivation practices adhered to the standard potato cultivation methods established by the Rural Development Administration [29]. During the elongation stage (45 days after planting), plant height, stem length, number of stems, and SPAD (chlorophyll content) were measured at each site. SPAD values were obtained using a SPAD-502 Plus meter (KONICA MINOLTA Co., Ltd., Tokyo, Japan). The harvesting dates for G1, G2, and G3 were 18–25 June, 11–18 June, and 4–10 June, respectively. At harvest, stem length, number of stems, and chlorophyll content were reassessed. Additionally, yield components including tuber number per plant, tuber weight per plant, and yield per ha were evaluated. Marketable yield was calculated as the proportion of total yield comprising potatoes weighing 51 g or more.

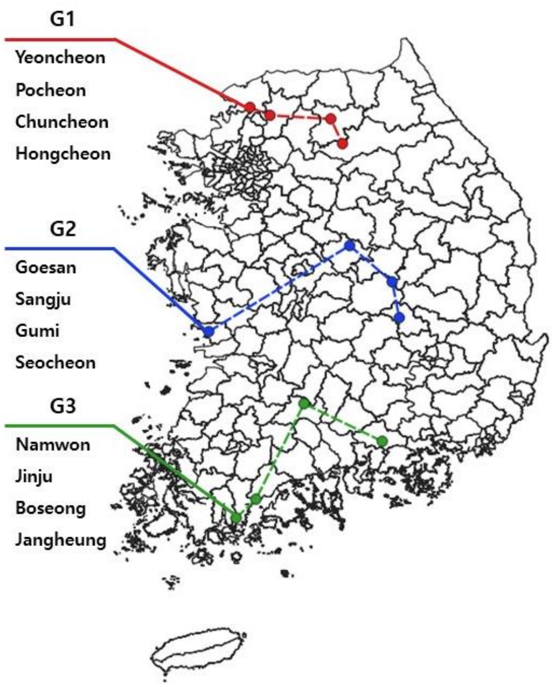

Figure 1. Experimental areas (G1, G2, and G3) used in this study.

2.3. Soil Chemical Properties Analysis in Climatically Diverse Potato Cultivation Sites

To evaluate soil chemical characteristics in potato fields, samples were collected during the potato elongation phase (45 days post-planting). An Edelman auger (Royal Eijkelkamp, Giesbeek, The Netherlands) with a 2 cm diameter was employed to extract approximately 200 g of soil from three locations at depths of 0–20 cm. Samples were air-dried at room temperature for one week and sieved through a 2 mm mesh prior to analysis. Analytical procedures followed the Rural Development Administration's agricultural science and technology research guidelines [54]. Organic matter content was determined via the Tyurin method, nitrate nitrogen by colorimetry following 2 M KCl extraction, and available phosphorus using the Lancaster method. Exchangeable cations (K, Ca, Mg) were quantified through atomic absorption spectroscopy after extraction with 1 N ammonium acetate. Soil pH and electrical conductivity (EC) measurements were conducted during both the elongation and harvest stages using a soil pH/EC meter (HI991300, Hanna Instruments Inc., Woonsocket, RI, USA). Readings were obtained from a 1:5 (w/v) soil–water suspension.

2.4. Climatic Factor Analysis Across Diverse Cultivation Sites

Meteorological data for the study period (February–June 2024) were obtained from the Agricultural Weather 365 platform (https://weather.rda.go.kr/ accessed on 10 July 2024). Daily maximum, minimum, and mean temperatures, along with precipitation, were analyzed for each cultivation area. Mean values for regions G1, G2, and G3, as referenced in the "Growth and Yield Differences in Potato Cultivation Across Diverse Climatic Distributions" study, were utilized. For locations lacking weather stations, data from the nearest available station were substituted.

2.5. Analysis of General Components and Secondary Compounds in Potatoes Harvested from Cultivation Areas with Diverse Climate Distributions

Potatoes harvested from various cultivation sites were stored at 15 °C for one week, peeled, uniformly cut, and dried at 50 °C for two days. The dried potatoes were ground using a coffee grinder (SHMF-3500TG, Hanil Electric Co., Wonju, South Korea), sieved through a 1 mm mesh, and prepared for analysis. General components were analyzed using the following methods [55]: moisture by atmospheric heat drying, crude protein via micro-Kjeldahl method, ash by incineration at 550 °C, and crude fat using the Soxhlet method. Total carbohydrate content was calculated by subtracting moisture, ash, crude protein, and crude fat from the total.

For secondary compound analysis, 0.5 g of ground potato from each region was processed with 5 mL of 100% methanol to measure total phenol, flavonoid content, and DPPH radical scavenging activity [56]. Phenol content was determined by mixing 1 mL supernatant with 3 mL distilled water and 1 mL Folin–Dennis reagent, agitating for 5 min, and measuring absorbance at 640 nm after 1 h at room temperature [57,58]. Flavonoid content was assessed by combining 0.5 mL supernatant with 95% ethanol, 10% $AlCl_3$, 1 M potassium acetate, and distilled water, and then measuring absorbance at 415 nm after 40 min at room temperature [57,58]. DPPH radical activity was evaluated by mixing 0.1 mL supernatant with 0.1 M acetate buffer, 0.5 mM DPPH, and ethanol, then measuring absorbance at 517 nm after 30 min at room temperature [57,58].

Vitamin C analysis involved suspending 0.1 g ground potato in 5% metaphosphoric acid, centrifuging, and measuring the supernatant's absorbance at 525 nm, using ascorbic acid as a standard [59]. Total glutathione content was determined similarly, with absorbance measured at 412 nm for 1 min, using glutathione as a standard [60].

3. Results and Discussion

3.1. Survey of Potato Cultivation Practices in Regions with Different Climate Distributions

A survey of potato cultivation practices was conducted across 45 farms in three distinct regions: G1 (Gangwon and Gyeonggi), G2 (Chungbuk, Chungnam, and Gyeongbuk), and G3 (Jeonbuk and Jeonnam). The results indicated that the planting dates were earliest in G3, followed by G2, and then G1. On average, the planting dates were February 23 for G3, March 8 for G2, and March 23 for G1, demonstrating that G3 planted 14 and 30 days earlier than G2 and G1, respectively (Figure 2). The average potato cultivation area per farm was approximately 1.4 ha, with the majority of farms planting the Superior variety. Other varieties cultivated included Bakjak, Dubak, Chubak, and Seolbong.

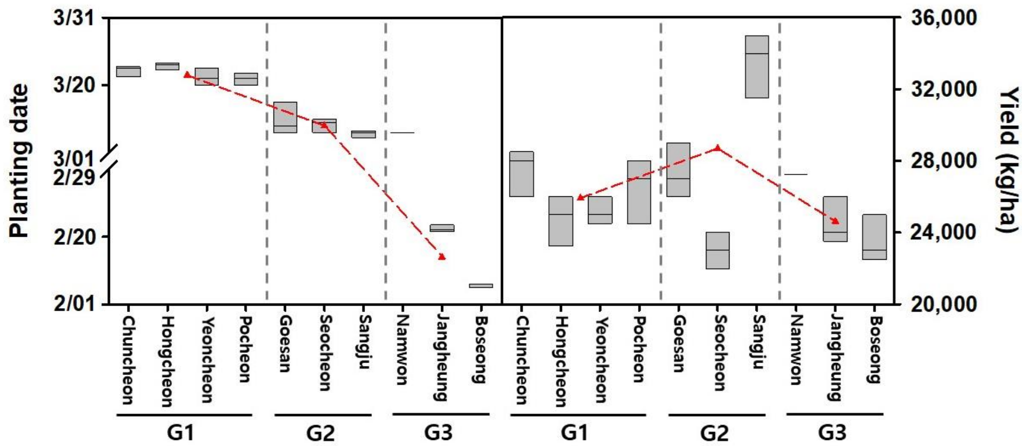

Figure 2. Planting date and potato yield across three region groups based on survey data collected from potato farmers (n = 45) in 2024. The boxes represent the interquartile range (IQR), with the lower edge indicating the 25th percentile (Q1) and the upper edge indicating the 75th percentile (Q3). The horizontal line within each box represents the median. The red line within each box represents the average for each group (G1, G2, or G3).

The seed potato supply system in Korea follows a multiplication scheme of basic seed, basic plants, foundation seed, registered seed, and certified seed for distribution to farms. Historically, the supply rate of certified seed was low, at around 25% [61]. However, this study's survey revealed that most farms currently use certified seed varieties, with some obtaining seeds from potato purchasers and others using tissue-cultured seed potatoes.

The survey indicated that potato yields per ha ranged from 22,500 to 35,000 kg, with notably higher yields observed in the Sangju area of the G2 region compared to other areas. When comparing groups, the G3 region showed slightly lower yields than G2 and G1. This reduction in yield was attributed to earlier planting and harvesting practices in G3, where farmers aim to harvest earlier than the expected harvest time to capitalize on higher market prices, potentially resulting in somewhat decreased yields.

3.2. Differences in Potato Growth and Yield Across Cultivation Areas with Varying Climate Distributions

Potatoes undergo five crucial developmental stages that determine harvest yield: sprout development, vegetative growth, tuber initiation, tuber bulking, and maturation [62]. An examination of potato growth during the tuber initiation phase across different planting regions revealed that plant height in the G1 area was shorter compared to G2 and G3 areas (Figure 3). Stem length exhibited a similar pattern, with G1 demonstrating shorter stems than G2 and G3. Stem count was marginally higher in G2 and G3 regions compared to G1, with Seocheon in G2 and Namwon and Jinju in G3 exceeding the average. Chlorophyll content, as measured by SPAD values, was higher in Yeoncheon and Pocheon of G1 compared to other areas; however, on average, there was no significant difference between cultivation groups.

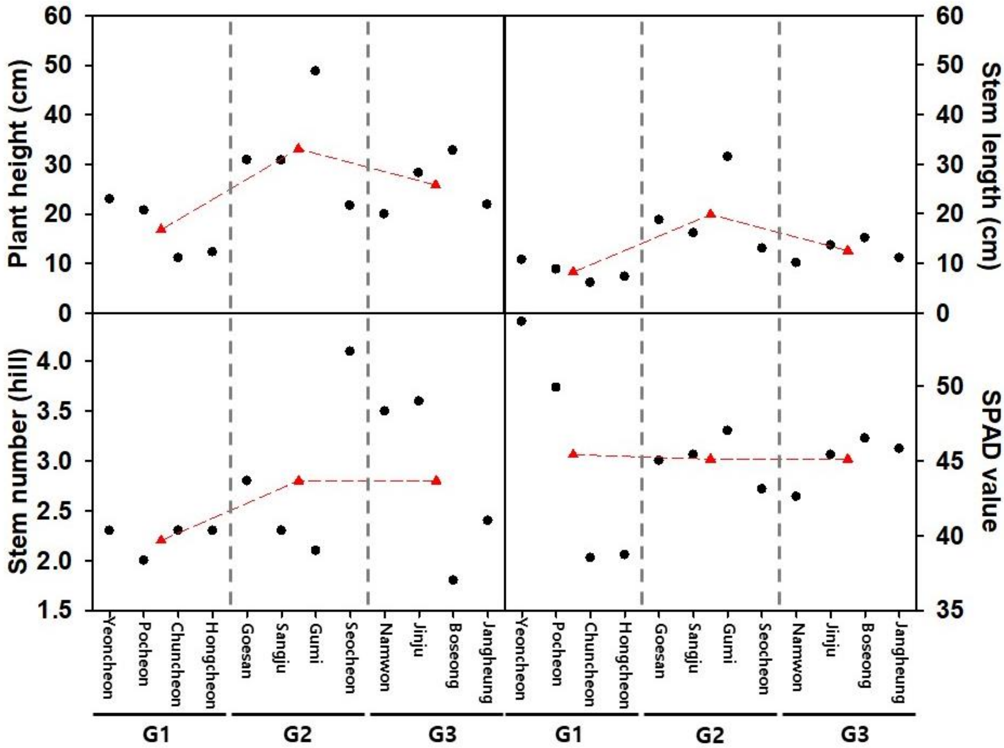

Figure 3. Growth and chlorophyll content (SPAD value) of spring potatoes in three regional groups at the tuber bulking stage. The red line within each box represents the average for each group (G1, G2, or G3).

At harvest time, stem length in G2 was shorter than in G1 and G3, contradicting the earlier observations during the tuber bulking phase (Figure 4). G3 exhibited a higher stem count per plant compared to G1 and G2, particularly in Seocheon (G2), Namwon, and Jinju (G3). Chlorophyll content decreased in the order of G1 > G2 > G3, likely due to accelerated plant senescence in southern regions with higher temperatures. Tuber count per plant was higher in G2 compared to G1 and G3, with notably high counts in Yeoncheon (G1), Sangju and Seocheon (G2), and Jinju (G3). Tuber weight per plant decreased in the order of G1 > G2 > G3, with Pocheon (G1) demonstrating the highest weight. The lower tuber weight in G3 is attributed to earlier harvesting for prompt shipment. Yield per ha was slightly higher in G2 compared to G1 and G3. However, when compared to the average, total yield per ha was higher in Chuncheon (G1) and Sangju (G2), but lower in Seocheon (G2) and Jinju (G3). Marketable yield was somewhat lower in G3 compared to G1 and G2, likely due to early harvesting resulting in more non-marketable produce. The marketable ratio was also slightly lower in G2 and G3 compared to G1. A similar study found that the potato variety 'Goun' (GU) demonstrated high yield (42,360 kg/ha) in Jinbu (E2) but low yield (22,300 kg/ha) in Daegwallyeong (E3), indicating significant differences based on local climate conditions [63]. The study also reported that different varieties were suitable for high yields in different regions: 'Sumi' in Gangneung, 'Goun' in Jinbu, and 'Haryeong' in Daegwallyeong [64]. This suggests that potato production levels vary depending on the cultivar. Potato yield is influenced by various factors including climate, cultivar, soil, fertilizer, and cultivation methods [65]. While it may not be possible to accurately predict potato yields for all regions in Korea, this study can be utilized for resetting optimal planting times and exploring suitable cultivation areas for potatoes in response to climate change.

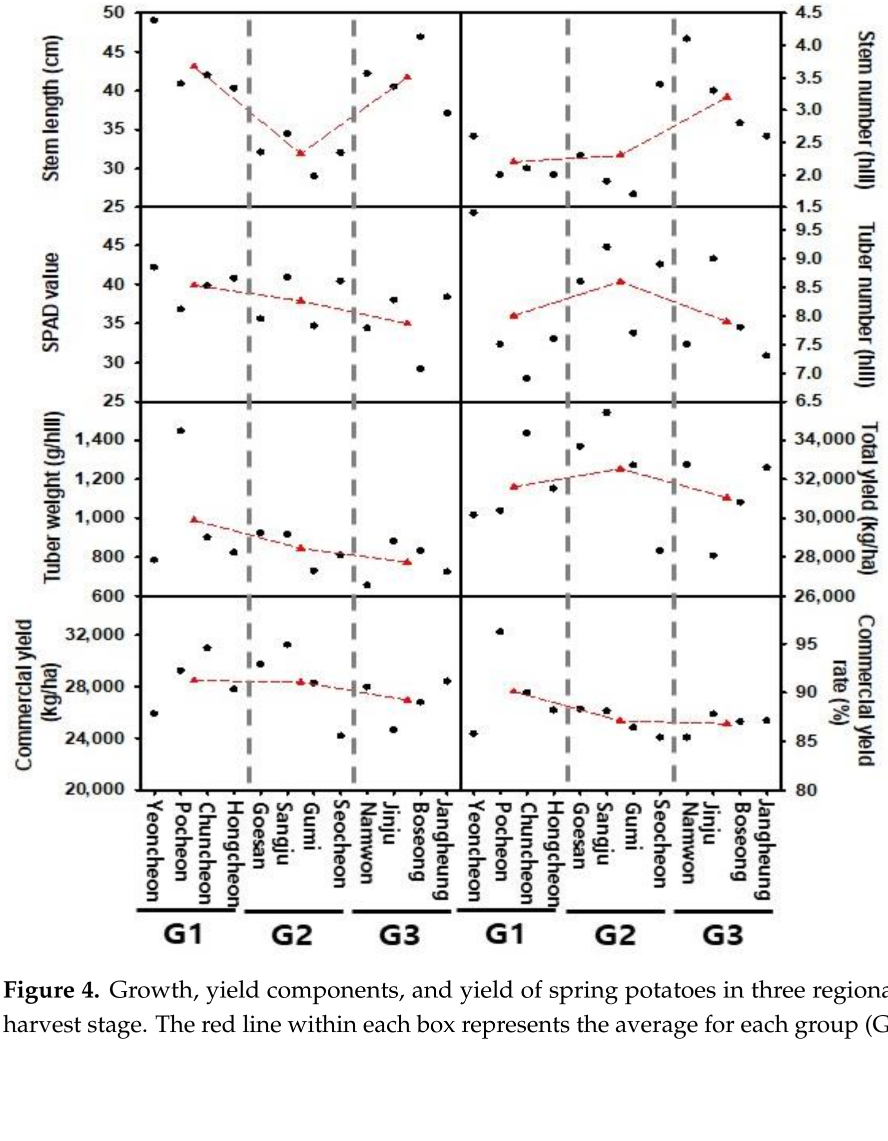

Figure 4. Growth, yield components, and yield of spring potatoes in three regional groups at the harvest stage. The red line within each box represents the average for each group (G1, G2, or G3).

3.3. Weather Factors and Yield in Potato Cultivation Areas with Different Climate Distributions

Potato yields demonstrate various fluctuations based on environmental factors such as maximum, minimum, and daily average temperatures, precipitation, and sunshine hours during the growing period [66–68]. Consequently, daily average, maximum, and minimum temperatures, along with precipitation, were examined for each cultivation region (Figure 5). Regarding daily average temperatures by region, the G3 area exhibited the highest temperatures from February to late March, corresponding to the potato planting, sprout formation, and vegetative development stages. The G1 area demonstrated lower temperatures, while the G2 area displayed intermediate trends. However, daily average temperatures from April to June, which encompass the tuber initiation, formation, and maturation phases, were comparable across all regions.

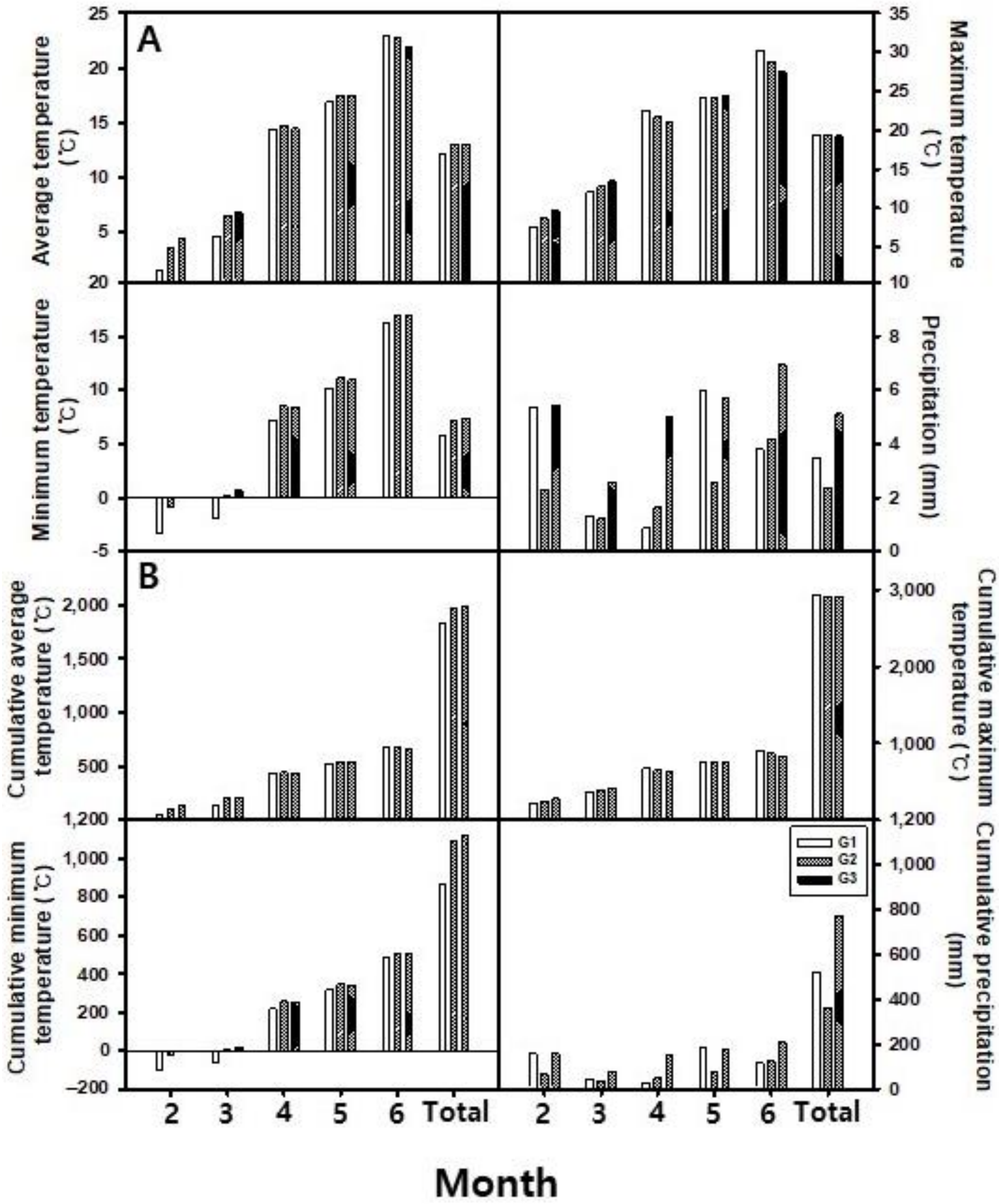

Figure 5. Temperature trends across three regional groups from February to June 2024. (**A**) Monthly average temperatures. (**B**) Cumulative temperature profiles.

During the sowing, sprouting, and vegetative growth stages, the maximum temperatures were highest in G3, followed by G2, and then G1. This observation suggests that the elevated maximum temperatures in G3 resulted in earlier sowing dates and accelerated growth. However, from April to the June harvest period, no significant differences in maximum temperatures were observed across regions. Minimum temperatures in G1 were comparatively lower than in G2 and G3. Notably, G1 frequently experienced temperatures below −5 °C in February, rendering it unsuitable for February sowing. Nevertheless, minimum temperatures after April were similar across all regions. Temperature is a critical factor for crop growth, development, and yield determination, with optimal temperatures varying depending on the growth stage. For instance, the optimal conditions for potato above-ground and below-ground (tuber) growth differ [32]. The ideal temperature for above-ground growth is 20–25 °C, while tuber formation and enlargement thrive at 15–20 °C [33]. In this study, the similar daily average, minimum, and maximum temperatures across regions during each growth stage of spring potatoes likely contributed to comparable potato yields. However, the higher potato yields observed in Chuncheon (G1) and Sangju (G2), compared to lower yields in Seocheon (G2) and Jinju (G3), may be attributed to varying crop responses to optimal temperatures and temperature stress. These responses can differ based on duration, intensity, occurrence period (day or night), rate of temperature change, and developmental stage [69].

Precipitation is another crucial weather factor. G3 experienced higher rainfall during the sowing and sprouting periods (February–March) compared to other regions, while G2 and G3 had very little precipitation. However, rainfall from April to June was similar across regions, except for a few observation days in G3. Typically, high rainfall and temperatures during the spring potato harvest in June and July can lead to deformed tubers and reduced quality [65]. However, recent trends indicate that potato harvests predominantly conclude in June. In this study, the average marketable tuber yield ratio exceeded 86% across regions, with no deformed tubers observed, suggesting that June rainfall did not negatively impact potato tubers. Similar research has demonstrated that marketable tuber yield ratios under drought stress were not significantly different from unstressed conditions. However, drought stress did reduce above-ground growth and shorten the growth period, resulting in substantially decreased yields [70].

3.4. Soil Chemical Properties of Potato Cultivation Areas with Varying Climate Distributions

To examine the soil chemical properties of potato cultivation areas, soil pH and EC were measured during the tuber bulking and harvest periods (Figure 6). The G1 region exhibited slightly higher pH levels compared to the G2 and G3 regions. This trend persisted during the harvest period, with G1 maintaining higher pH levels than G2 and G3. Notably, Chuncheon in G1, Goesan in G2, and Namwon in G3 displayed elevated pH levels during both periods. The pH range for potato cultivation areas in this study was 5.1–6.6, which aligns with findings from another study that reported a soil pH range of 5.0–6.9 [71].

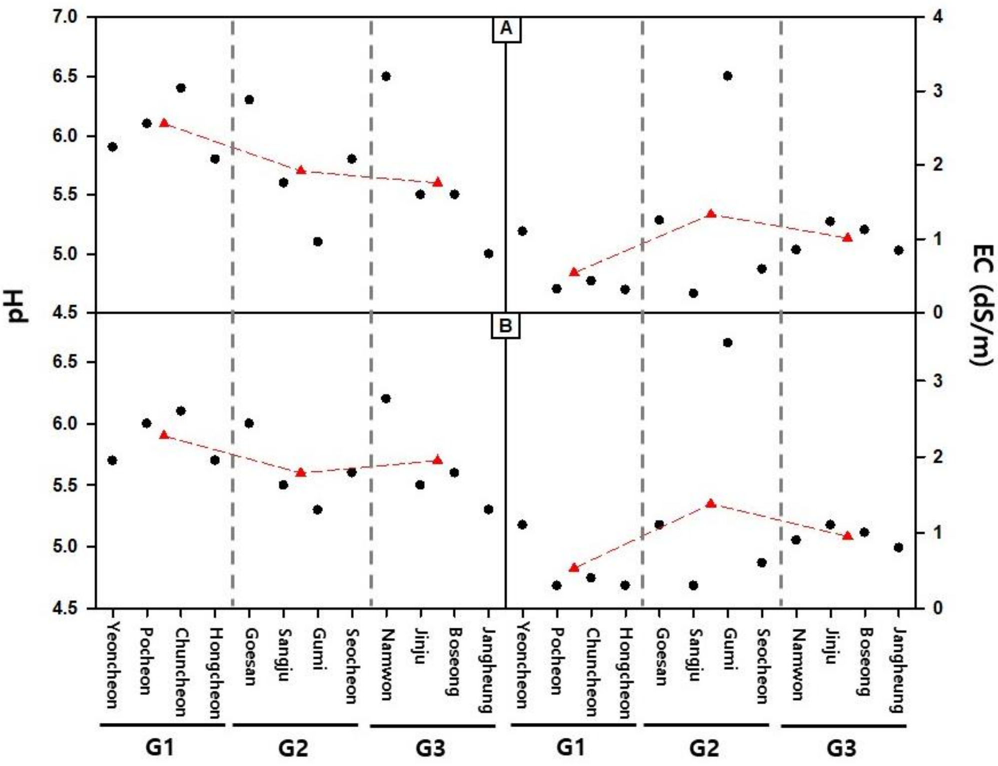

Figure 6. Soil pH and electrical conductivity (EC) across three regional groups during tuber bulking (**A**) and harvest (**B**) stages. The red line within each box represents the average for each group (G1, G2, or G3).

EC measurements during the elongation period revealed higher levels in G2 and G3 regions compared to G1. Similar results were observed during the harvest period. Gumi in the G2 region exhibited an EC of 3.2 dS·m^{-1} during both periods, while other areas remained below 1.1 dS·m^{-1}. Potatoes have been classified as a salt-sensitive crop [72], with reports suggesting negative yield impacts even under relatively low salt conditions (EC 1–2 dS·m^{-1}) [73]. However, this study and others have found that potato cultivation areas typically have low soil EC levels of 1.1 dS·m^{-1}, indicating no adverse effects from EC [71]. An analysis of soil chemical properties in potato cultivation areas revealed that organic matter content ranged from 6.0% to 6.7% across regions, exhibiting minimal variation (Figure 7). However, a study examining soil organic matter after planting 'Hongyoung' and 'Jayoung' colored potatoes in 14 nationwide locations found significant regional differences, with Pyeongchang (Jinbu) having the lowest at 0.9% and Naju the highest at 6.2% [71]. Nitrate nitrogen content demonstrated little regional variation, except for the G1 region of Yeoncheon. Effective phosphorus content was notably higher in Yeoncheon (G1) and Gumi (G2) compared to other areas, with average levels decreasing in the order of G1 > G2 > G3 regions. Another study on potato fields reported a substantial difference in effective phosphorus content between sandy soil in Boseong (146 mg/kg) and well-cultivated paddy soil in Naju (1235 mg/kg). Thus, the regional variations in effective phosphorus content observed in this study may be attributed to differences in soil texture. Exchangeable cation levels of Ca and Mg were similar in G1 and G2 regions but lower in G3, while K content was comparable in G1 and G3 but higher in G2. Soil chemical properties in cultivation areas are influenced by various environmental factors, including crop type, rhizosphere, soil temperature, pH, and inorganic components [74]. Ultimately, the increasing occurrence of abnormal weather due to accelerated global warming is anticipated to impact crop canopy structure and soil chemical properties, potentially affecting crop yield and quality.

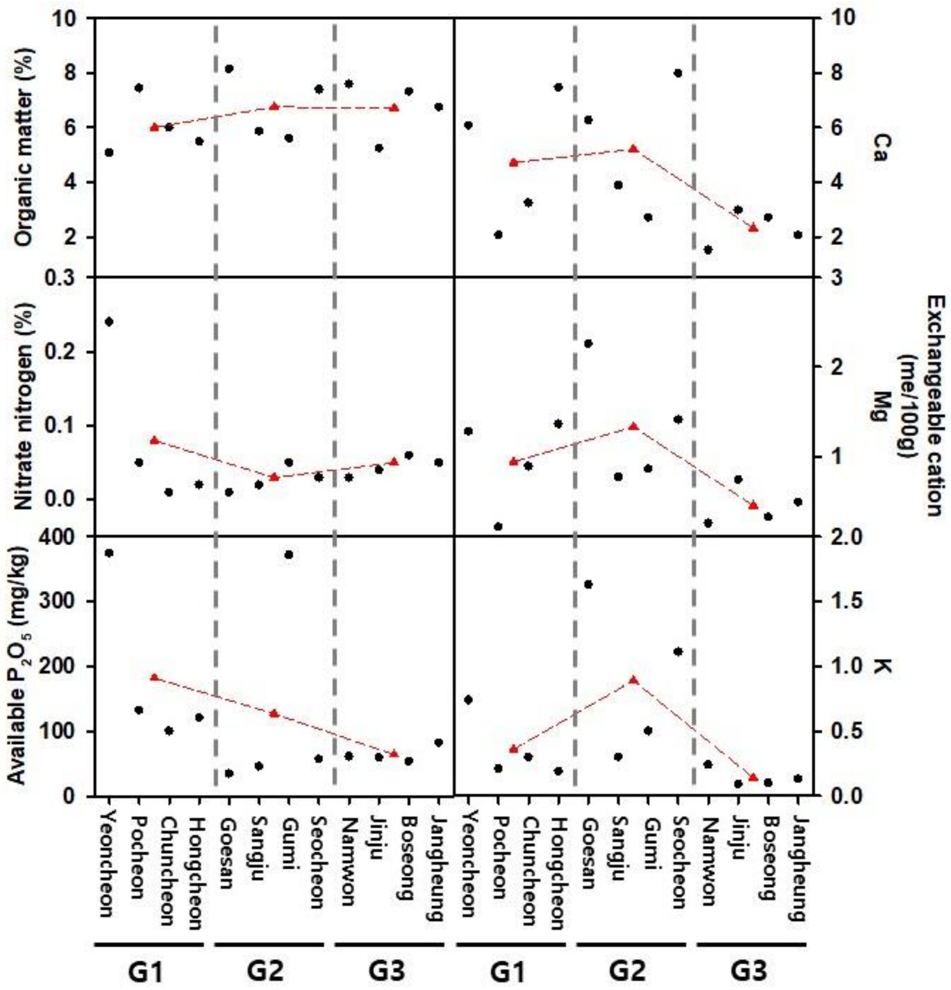

Figure 7. Distribution of major soil nutrients concentrations across three regional groups during the tuber bulking stage in 2024. The red line within each box represents the average for each group (G1, G2, or G3).

3.5. Differences in General Components and Secondary Compound Content of Potatoes Harvested from Cultivation Areas with Varying Climate Distributions

The general components of potatoes, including moisture, crude fat, crude protein, ash, and carbohydrates, were analyzed for potatoes harvested from different regions (Figure 8). Moisture content in potatoes from G1 and G3 regions exhibited minimal variation, while potatoes from G2 regions demonstrated higher moisture compared to G1 and G3. Crude ash content was consistent across all regions. Crude fat content was comparable in all G1 regions, Goesan, Sangju, and Gumi in G2, and Namwon in G3, but significantly lower in Seocheon (G2) and Jinju, Boseong, and Jangheung (G3). Crude protein content was similar in G1 and G2 regions but marginally lower in G3. Carbohydrate content was relatively higher in G3 compared to G1 and G2 regions. Generally, potato protein content is reported to be less than 10%, with 2% in fresh potatoes and 7.9% in dried potatoes [75,76]. In this study, protein content averaged approximately 8%, with minor variations among cultivation areas. However, potato tubers not experiencing drought near harvest time exhibited a 26–30% increase in protein content compared to those affected by drought [77]. Thus, climate change and abnormal weather patterns may alter the nutritional composition, including protein content, of potato tubers. Ascorbate content was similar in G1 and G2 regions but elevated in G3. Jinju in G3 exhibited the highest ascorbate content, while Chuncheon in G1 demonstrated the lowest (Figure 9). Glutathione content was highest in

G3, followed by G1, and then G2, with G3 displaying notably higher levels compared to G1 and G2 regions.

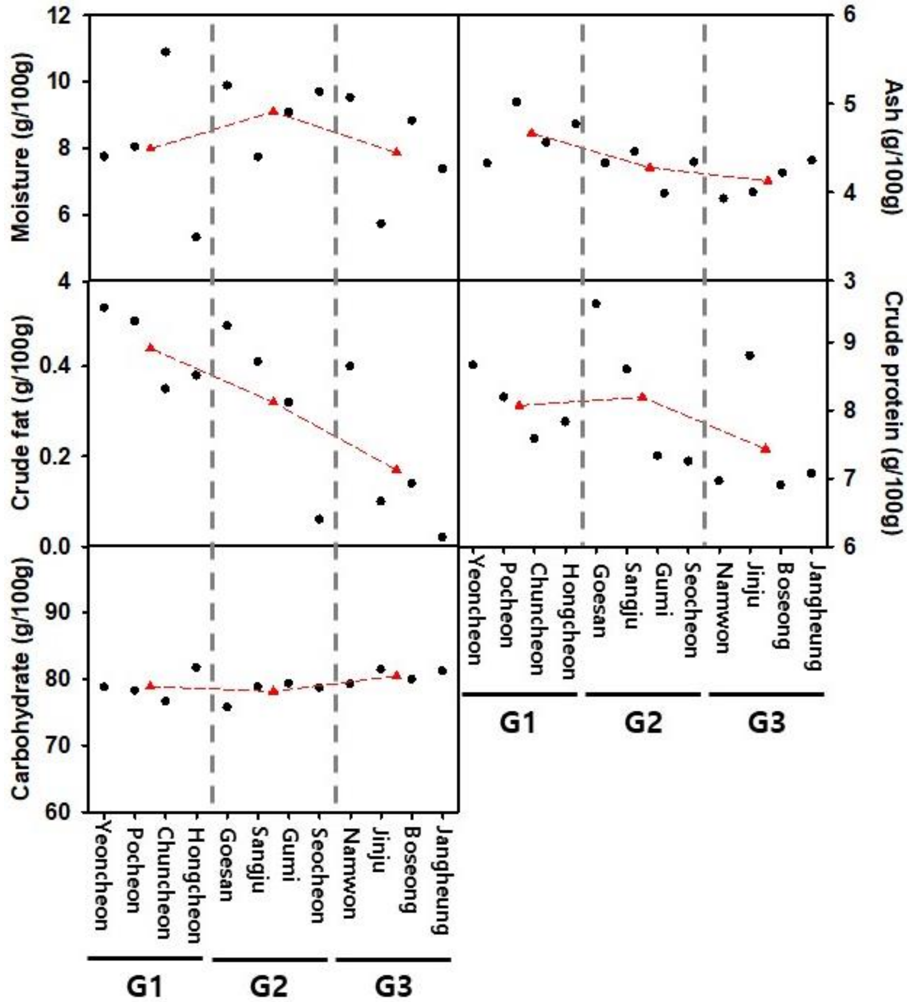

Figure 8. Key components of potatoes harvested from three regional groups in 2024. The red line within each box represents the average for each group (G1, G2, or G3).

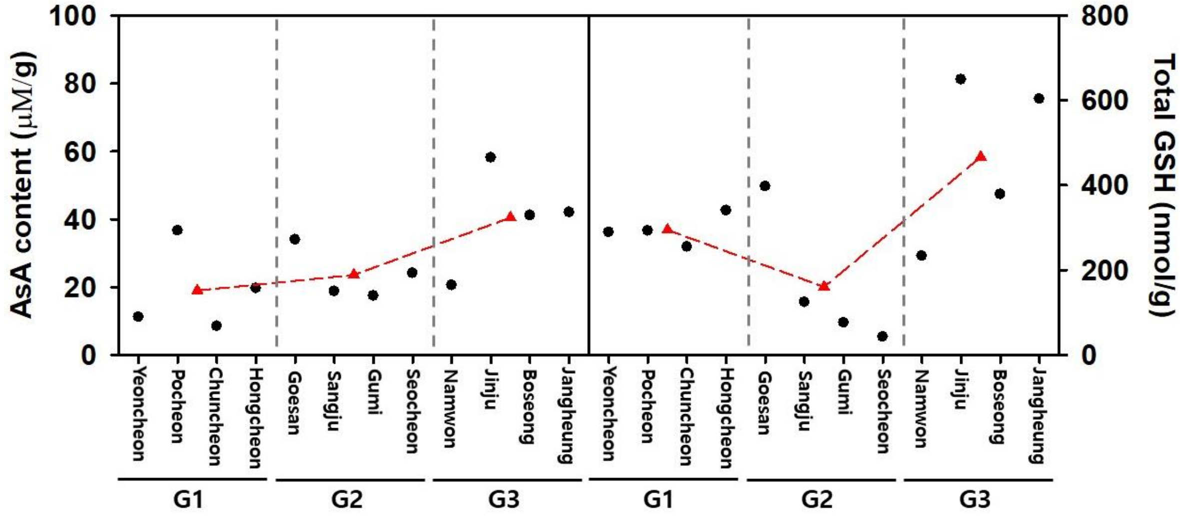

Figure 9. Ascorbate (AsA) and glutathione (GSH) levels of potatoes harvested from three regional groups in 2024. The red line within each box represents the average for each group (G1, G2, or G3).

Potatoes contain numerous secondary metabolites due to their botanical characteristics [78]. When utilized appropriately, potatoes can meet consumers' demands for health foods. Consequently, an investigation of secondary compounds in potatoes harvested from different cultivation areas was conducted (Figure 10). The content of phenols and flavonoids exhibited minimal variation across regions G1, G2, and G3. However, DPPH radical scavenging ability was higher in G2 and G3 compared to G1, with particularly low levels observed in Chuncheon and Hongcheon areas within G1. A study on potato cultivation using various mulching film types (black, colored, transparent) reported superior total phenol and DPPH content under colored film conditions [21]. Additionally, an analysis of anthocyanin content in 'Jasim', the first domestically developed colored potato, planted in lowland Gangneung, semi-highland Jinbu, and highland Daegwallyeong, revealed higher concentrations in potatoes produced in highland areas [79]. Although this study found some regional differences in DPPH radical scavenging ability, overall secondary compound levels did not significantly differ among cultivation area groups (G1, 2, 3).

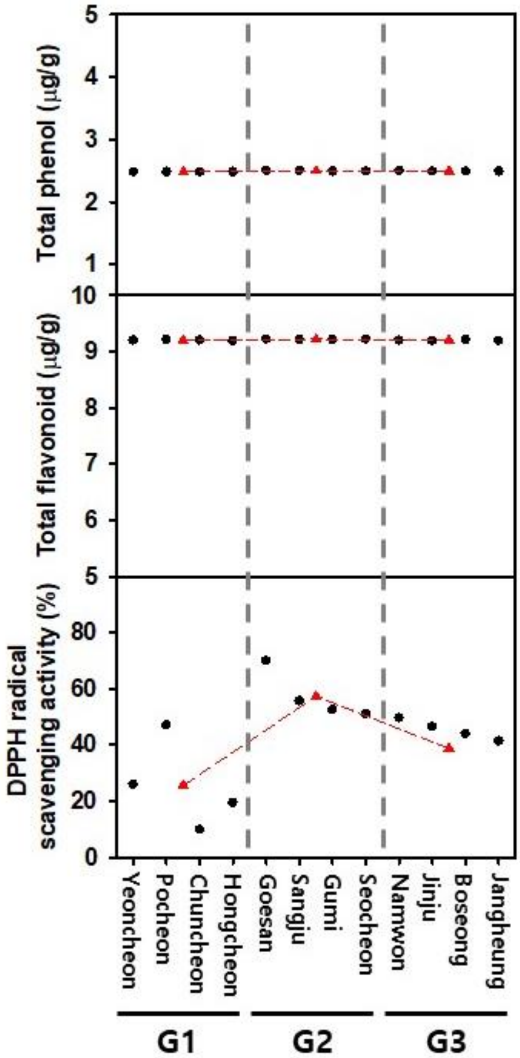

Figure 10. Total phenol, flavonoid levels and DPPH radical scavenging activity (%) of potatoes harvested from three regional groups in 2024. The red line within each box represents the average for each group (G1, G2, or G3).

4. Conclusions

This study examined the impact of variable weather conditions on potato growth and yield across three regions with distinct climate distributions in Korea. Our findings indicate that weather factors such as temperature, precipitation, and soil chemical properties have significant but varying effects on potato growth and yield across the regions. Despite the differences in planting dates and environmental conditions, the yield differences between the regions were generally minimal, with G2 showing slightly higher yields than G1 and G3. The early planting and harvesting practices in G3 were associated with slightly reduced yields due to accelerated plant development. Soil pH and electrical conductivity (EC) varied across the regions, with G1 exhibiting slightly higher pH levels. However, the minimal variation in soil chemical properties did not show significant effects on potato yield, suggesting that other factors, such as temperature and precipitation patterns, may play a more dominant role in determining yield outcomes. The weather data analysis revealed that maximum temperatures were highest in G3, accelerating plant growth and earlier harvests. However, this also led to a reduction in marketable yields in G3 due to early harvesting. Although there were variations in climate-related factors, the overall yields remained comparable across regions, indicating that potato cultivation in Korea can be relatively resilient to moderate climate variations. In terms of nutritional composition, secondary metabolites such as phenols, flavonoids, and antioxidant activity did not show large regional differences, but the G3 region exhibited higher levels of ascorbate and glutathione. This suggests that climate variability can influence the nutritional profile of potatoes, potentially offering opportunities for optimizing potato cultivation for health benefits under changing environmental conditions. Overall, this study underscores the need to consider regional climatic factors and planting practices when determining optimal potato cultivation strategies. It also highlights the potential of using climate-resilient potato varieties and adjusting farming practices in response to ongoing climate change.

Author Contributions: Data curation, E.E. and H.H.P.; review and editing, Y.I.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. RS-2024-00361442)" Rural Development Administration, Republic of Korea.

Data Availability Statement: Data are contained within the article.

Acknowledgments: The authors acknowledge the help of Hee Kwon Kim, Byung Joon Jeong, Yeon Hu Woo, and Ji Young Nam in crop cultivation.

Conflicts of Interest: The authors declare no conflicts of interest.

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