Study on seedling cultivation using buds of potato (*Solanum tuberosum* L.)

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Abstract

Background: The world is facing numerous challenges in food production due to unstable climate change. There is a strong need to develop the various techniques of crop production, which could greatly help fulfil the demand for better crop production within a short time period.

Methods: In this study, a bud planting method was adopted to cultivate potato seedlings. For this purpose, we assessed different types of treatments for producing quality buds and seedlings of potatoes. Total 4 disease-free potatoes (Fujin, Youjin, Zhongshu 4, and Feiwuruita) were selected. Potato buds with three different lengths (3cm, 5cm, and 7cm) were considered T1, T2, T3 treatments, and terminal buds, middle buds, and tail buds were used as T4, T5, and T6 treatments, respectively. The experiment was performed in nutrient pots using a randomised complete block design (RCBD) and replicated thrice compared with the natural control (CK) treatment. The cultivation was done by adopting the common horticultural practices of weeding and hoeing as needed for growing conditions. The photosynthetic indexes, physiological indexes, growth indexes and quality of potato seedlings, potato bud quality were measured at two weeks intervals, and yield indexes were measured when the final crop was harvested 14 weeks after planting.

Results and Conclusions: The obtained results depicted that seedling cultivation of potato bud with different lengths increased the reproduction coefficient as well as reduced the number of seed potatoes used for cultivation. All the morphological, physiological and yield indexes were also improved in a positive trends. The 7cm potato bud length was proven as the best treatment among the different treatments used for raising seedling. Different parts of potato bud also showed the formation of the best quality bud at the top section of the potato. In crux, we hypothesised that our proven bud planting technique should be adopted commercially, which could help in good crop production with maximum yield.

Key words: Potato; Seedling cultivation; Production; Potato bud; Yield

Introduction

Potato (*Solanum tuberosum* L.) isa well-known tuber crop around the world, and approximately 1.3 billion people consume this crop as a staple food (*Stokstad, 2019*). Potatoes are native to the Andes mountains of South America, with an altitude of 2000-4000 M. The environmental characteristics are short daytime, high light intensity, low temperature and high relative humidity (*Harris, 2012*). After hundreds of years of domestication, this crop was primarily introduced into Europe in the 1970s. It is being cultivated in several countries and regions between 65°N and 50°S of the world (*Camire et al., 2009*). This crop is also used as an important industrial raw material for the production of starch, ethanol and animal feed (*Birch et al., 2012*).

A potato tuber is a modified stolon which is a rich source of nutrition intake due to stored starch, protein, vitamins and minerals (*Aien et al., 2011; Hancock et al., 2014*). This tuber is an expanded stem with terminal buds and lateral buds, and these buds enter into a dormant state after separating from the mother part. Tuber formation begins with the inhibition of longitudinal growth at the end of stolon, and then the terminal bud begins to expand due to cell division and cell expansion (*Cutter, 1978*). The formation of potato tuber is generally depended upon favorable climatic conditions.

A number of different planting techniques have been introduced to get suitable potato production. Among them, potato bud planting technology achieved the purpose of restoring seeds with virus-free and strong disease resistance characters at an early stage. When the late blight occurs in rainy season of July/August, then potato crop is being to be harvested or close to its maturity level (*Luo and Jin, 1960*). The breaking off potato buds dormancy, raising of seedlings in the seedbeds, and transplanting them to proper field for rapid seed propagation could save up to 39.3% of seed potatoes amount (*Wu et al., 2009; Li, 2014*). When the seedling reach at 5 cm height, it bear a large number of fibrous roots in the soil, then it should be detached from the seed potato for transplanting, which could increase the reproduction coefficient of virus-free seed potato (*Xiong et al., 2010*).

The cultivation of potato bud seedlings is mainly linked with the potato planting method of seedling transplanting, which is primarily based on the cultivation of potato bud as seed. Bud planting technology has the characteristics of multiple reproduction, fast reproduction, and guaranteed crop cultivation, and this method been used in traditional Chinese medicine crops (*Yu et al., 1999; Wen et al., 2000*) and vegetable crops (*Li, 1962*). The potato bud planting method was introduced in 1960s and has been tested in different provinces (Shanxi, Zhejiang, Jilin, Heilongjiang, Qinghai and other areas) of China (*Li, 1959*), respectively. The planted potatoes' buds are accelerated in semi-humid soil under a suitable temperature of 20-25℃. The length of speedy germination can reach 3.5-10.5cm growth in 8 days, and the survival rate of transplanting is relatively high (*Liu, 1962*). When seedlings reached at 6-10cm height and 5-7 leaves numbers, then seedlings were cut off from the base and planted in time. The yield was higher than traditional direct seeding with buds (*Zhang and Tian, 2012*).

It has been shown that when the bud length of seed potato reaches 2.5cm, crop production with the method of 2.5cm length bud could increase up to 89.4% compared to the conventional method of direct potato seeding (*Lv and Jiang, 1992*). The cultivation of potato seedlings was in favor of reducing the occurrence of potato late blight disease and also reduced the probability of plants degradation (*Chen, 2014; Chen and Jiang, 2015*). A study showed that the much older seed tuber buds produce a higher yield. The bud planting method saves the number of seed potatoes as compared with the direct planting method (*Liu et al., 1990*). The traditional way of natural bud seeding yield 200-300 kg/mu of potatoes, but the cultivation through the bud-seedling planting method only need 40-50 kg/mu, which could save nearly five times seed potatoes (*Li, 1982*).

The raising of the vegetable seedlings is primarily linked with vegetable cultivation (*Wen and Li, 2001*). Seedling cultivation is one of the fundamental measures to check and improve the emergence rate and cultivate strong seedlings during vegetable production. It has numerous advantages of enhancing the precocity of vegetables, increasing yield, and increasing the economic income for farmers. At present, potato's protected culpotatoeson mainly ddependent upon the direct seeding of tubers, which has the crucial disadvantages of large seed consumption and low reproduction coefficient (Fig. 1A). However, using the potato buds for seedling cultivation can effectively reduce its seed consumption, increase the reproduction coefficient and increase the overall efficiency of the crop. Very little is reported on potato seedling cultivation through buds usage. So, the undertaken experiment laid the adaptability and feasibility of potato seedling cultivation using the different buds length in protected nutrient pot. The authors found that potato bud-seedling cultivation is conducive to early maturity and yield improvement.

Materials & Methods

Source of material & cultivation

Total four virus-free potatoes (Fujin, Youjin, Zhongshu 4, and Feiwuruita) were used as experimental varieties which were collected from Jilin Academy of Agricultural Sciences, China.

These materials were healthy seed potatoes having excellent phenotypes of diameter, height, shape, and good bud development. The cultivation of these experimental materials was grown in a greenhouse of a practical experiment farm of Jilin Agricultural University, China. The sandy loam soil was arranged, and farm manure was mixed in it. The mixed soil was filled in nutrient up to 30cm of depth, pot The physical and chemical properties of soil were ranged comprising of total nitrogen 1.41 g/kg, total phosphorus 0.34 g/kg, total potassium 8.9 g/kg and organic matter 40.6 g/kg.

Experiment design and measurements

The seed potatoes were selected on the basis of their significant morphological characteristics and without any visual abnormality. Three independent trials were carried out in all the cases.

(1) Raising of seedlings and cultivation of different potato bud lengths: The length of potato bud was divided into three treatments of 3cm±0.5cm, 5cm±0.5cm, and 7cm±0.5cm, respectively. The virus-free seed potato of the same size, and strong dormancy period were used to promote the germination under dark light period. When the bud length reaches at 3cm±0.5cm (seed potato treatment for 8-9d, T1), 5cm±0.5cm (seed potato treatment for 10-11d, T2) and 7cm±0.5cm (seed potato treatment for 12-13d, T3) (Fig. 1B), then potato terminal buds were selected and bud breaking treatment was done. The buds were broken from basal ends, sown into nutrient bowl having equal size of 10cm×10cm. Seedlings were successfully raised in the greenhouse on March 25, and 25 days old seedlings were then planted in the greenhouse on April 20.

(2) Raising of seedlings and cultivation of different parts of potato buds: Three treatments of terminal bud (T4), middle bud (middle part of seed potato, T5) and tail bud (basal bud, T6) were set at different sections of potato bud. When the length of the potato bud was 5cm±0.5cm (seed potato treatment for 10-11d) (Fig. 1C), then bud breaking treatment was carried out from the basal part of the potato bud, and the other methods were the same as described in the above part 1.

(3) The cutting of seed potato seedling and cultivation in a nutrient bowl (CK) (Fig. 1A): The seed potato was taken out from the storage pit and placed in an incubator light under 20℃ temperature and 60% humidity. When the bud length reached 1-2cm, then the bud was cultured under indoor scattered light for 2~3 days. The seed potato was cut into bud blocks having 20g weight, sown into the same nutrition bowl of 10cm×10cm, and one plant per bowl was successfully developed. The seedlings were raised in greenhouse on 17 March, and when the seedling age was 25 days old, then transferred into the greenhouse on 2 March, all seedlings grown together.

Total three experimental trials were collectively cultivated in raised beds of 1.2m width, 5m length, 10cm height and protective transparent film coverage was applied. For double row cultivation, the row spacing of plants on the border was 25cm×40cm. The experiment was repeated 3 times and arranged in randomised complete block designs (RCBD) manners. All the agronomic practices, e.g., watering, fertilisation, temperature, and humidity, were maintained according to the needs and production routine.

Sampling and measurements

Measurement of photosynthesis rate and chlorophyll contents

The photosynthesis rate of potato seedlings was determined at suitable time of 9:30 am to 11:30 am. Ten leaves samples (each sample was third mature leaflet from top to the bottom of plant) were carefully selected for photosynthetically active radiation (PAR). Then, photosynthetic rate (Pn), transpiration rate (Tr), and stomatal Conductance (Gs) was determined by using a LI-6400XT photosynthetic apparatus (LI-COR, Inc., Lincoln, NE, USA). The illumination intensity was 1,600 μmol photons m^2/s, and gas flow rate was 500 mmol/s, concentration of cuvette CO_2 was set at 400 mmol CO_2/mol air, and the chamber temperature was 28°C. Then, the mixture was centrifuged with 85% (v/v) acetone solution for chlorophyll extraction, and spectrophotometric (HALO DB-20, Calamb, UK) measurements were obtained at 663 and 645 nm (*Paul and Driscoll, 1997*). The leaves of potato were sampled for determination of total chlorophyll contents in plants.

Measurement of agronomic parameters

The diameter of stem was measured from 5 replicates of standing field plant by using an electronic vernier calliper (instrument precision, 0.01 mm) as mentioned earlier (*Chang et al., 2016*). The length and height of the potato stem were measured using the measuring ruler having a 1 mm scale. A total of 5 plants were selected from each treatment, readings were taken 3 times, and the average value was calculated for determining the number of compound leaves per plant. The area of the compound leaf was measured at the seedling stage and tuber expansion stage. For this purpose, 5 plants were randomly selected and measured from each treatment for 3 times by using a handheld laser leaf area meter (Ci-203, CID, Inc., Vancouver, WA, USA) .

Potato plants were harvested for the measurements of agronomic parameters. The above-ground biomass was earthen up and measured after plants were oven-heated at 70°C temperature. The dry matter of plant organs (leaves, stems, roots, stolons and tubers) were weighted after detaching them from plants. The ratio of organs dry matter = the organ (leaf, stem, root, stolon, tuber) weight / the above ground biomass×100%; the ratio of root shoot = the root dry weight / the shoot dry weight×100%; the sound seedling index = (stem diameter / plant height + root dry weight / shoot dry weight) × (root dry weight + shoot dry weight).

Root activity was analysed by the triphenyl tetrazolium chloride (TTC) method (*Wang et al.,* 2006). TTC is a chemical that is reduced by dehydrogenases, and mainly succinate dehydrogenase when added to a tissue. The dehydrogenase activity is regarded as an index of the root activity. In brief, 0.5 g of fresh root was immersed in 10 ml of an equally mixed solution of 0.4% TTC and phosphate buffer, and kept in the dark at 37°C for 2 h. Afterward, 2 ml of H_2SO_4 (1 mol/L) was added to stop the reaction with the root. The root was dried with filter paper and then extracted with ethyl acetate. The red extractant was transferred into the volumetric flask to reach 10 ml by adding the ethyl acetate. The absorbance of extract at 485 nm was recorded.

Finally, root activity was expressed as TTC reduction intensity. Root activity = amount of TTC reduction (μg) / fresh root weight (g) × time (h).

Determination of potato yield and quality

After the harvesting, the total tubers at each sub-plot were weighed for yield assessment using an electronic scale, and the number of tubers per plant was counted. Relative yield = total yield of each treatment / yield of CK. The starch content of the plant sample was assayed as reported earlier (*Grechi et al., 2007*) method. After removing the plant residue, tissue starch was extracted by 80% (v/v) ethanol. After adding 3% HCl to the residue, the spectra were determined by photometric determination at 490 nm by the phenol-sulfuric acid method. A glucose calibration curve was established to calculate tissue starch content, expressed in mg/g dry weight.

For determination of reducing sugar, each reducing sugar sample was collected and placed into three test tubes with pistons. The filtrates of centrifuged potato tuber was grinded into liquid (0.2 mL), and distilled water (1.8 mL) were added to the test tubes. The determination method of reducing sugar was the DNS (*Miller, 1959*) method. The recorded data was substituted into a standard curve to calculate the reducing sugar content of grinded potato tuber liquid. The crude protein was detected by Coomassie brilliant blue staining (*Gao, et al., 2014*), and vitamin C was determined by molybdenum blue colourimetry (*Li, 2000*).

Data analysis

The recorded data was statistically analyzed by using the statistics program SPSS 20.0 (SPSS Inc., Chicago, IL, USA). A one-way analysis of variance (ANOVA) with posthoc tests (Tukey) was used to establish differences among treatments. The mean values showing significant differences were compared with the Tukey test at a 5% level.

Results

Effects of seedling raising on physiological indexes and growth indexes of potato at seedling stage

The chlorophyll content and net photosynthetic rate of developed seedlings with different tuber bud lengths showed the highest values at T1, followed by T2, and T3 showed the lowest values, but they were significantly different from those treated with CK, as shown in Table 1. The potato seedlings were obtained by using different parts of potato buds to cultivate seedlings in nutrient bowls, and the results of physiological indicators of each seedling stage were analysed and shown in Table 2. The chlorophyll content and net photosynthetic rate were responsive to the following treatments T4>T5>T6>CK, and T4 and T5 treatments were significantly different from T6 and CK, respectively, but no significant difference was observed between T6 and CK. The net photosynthetic rate determination was not significant for nursery treatment of T5, T6 and CK. The transpiration rate and stomatal conductance decreased in turn in the four treatments of the same variety, and the tested potato varieties showed consistency.

Effects of seedling raising on growth indexes and quality of potato plants at seedling stage

There were significant differences in plant height, stem diameter, and number of compound leaves of potato at seedling stage among the treatments with different length of potato bud (Table 3). The seedling cultivation with 7cm potato bud was noticed as the longest seedling as compared to 5cm seedling treatment and 3cm seedling treatment, and the difference was significant; however, overall three treatments results were much higher than CK treatment.

Regarding the plant height, stem diameter and number of leaves, T1 treatment of 'Fujin' variety increased by 49.63%, 60.94% and 58.81% as compared with CK, respectively. The T1 treatment of 'Youjin' increased by 21.80%, 57.83% and 43.61% as compared to CK; and T1 treatment of 'Zhongshu 4' was 49.12%, 51.09% and 40.93% higher than that of CK; then T1 treatment of 'Feiwurita' increased by 37.38%, 44.7% and 35.69% with CK. The quality difference of potato seedlings at seedling stage under the treatment of different potato bud lengths was as followed; the above-ground dry weight, underground dry weight, root-to-shoot ratio, root vigor, and strong seedling index of different potato bud length were T1>T2>T3>CK. The potato bud seedlings of three lengths were significantly different from CK treatment (Table 4).

Further, different parts of potato buds were used for seedling cultivation in a nutritional bowl and research results at seedling stage are shown in Table 5. The plant height, stem diameter and a number of compound leaves of each treatment in the same variety showed T4>T5>T6>CK, and the potato terminal bud treatment was higher with significant differences as compared to the CK levels. All the tested varieties showed the same performances, and the indexes of plant height, stem diameter and leaf number of 'Fujin' increased by 32.10%, 43.94% and 35.29%, and "Youjin" increased by 11.01%, 48.44% and 22.95%, respectively, 'Zhongshu 4' increased by 31.40%, 35.62% and 20.37%, 'Feiwurita' increased by 20.00%, 27.85%, and 17.24%, and all of above increments are very much as compared with CK treatment levels, respectively.

The effects of potato bud seedling raising at different parts on potato seedling quality are shown in Table 6. It can be seen that the above-ground dry weight of seedling raising treatment was higher than CK level, and four varieties depicted consistent results. The dry weight of the above ground and the dry weight of the underground part of the potato top bud seedling cultivation treatment was significantly different from that of CK. The root activity and seedling index of all tested varieties were T4>T5>T6>CK, and the performance trend of all varieties was the same.

Effect of seedling cultivation on potato plants in greenhouse

By comparing the plant growth of potatoes treated with different lengths of potato buds during the tuber expansion stage, it was found that three growth indicators of plant height, stem thickness, and leaf area in each treatment and within the variety were different, as followed by T1>T2>T3>CK. The treatments were significantly differed and performance trends of four experimental varieties were consistent.

Among the all treatments, the plant height increased at maximum level of 37.63% in T1 treatment of ‘Feiwurita’ variety and the stem thickness and leaf area were increased the most in T1 treatment of 'Feiwurita', which were 37.32% and 16.84% respectively (Table 7). The comparison of plant growth in potato buds at different positions during the expansion period of potato tuber showed from Table 8. Meanwhile, in the potato tuber expansion period, the three growth indicators of plant height, stem thickness, and leaf area were all shown as follows for each variety treatment T4>T5>T6>CK. Among them, the highest plant height was 69.52cm in potato top bud seedling cultivation of variety ‘Eugene’, the maximum stem thickness was 15.99mm for ‘Zhongshu 4’, and the leaf area of ‘Zhongshu 4’ was the highest as 6810cm^2. By comparing with the control plant height, the highest increase in stem thickness was the cultivation of 'Fujin' potato top bud cultivation, increasing by 24.31%, 31.28%, and 13.55% (Table 8).

During the expansion stage of potato tuber, the dry matter distribution rate of potato tuber in different tissues and organs was the highest, and order from large to small was tuber, stem, leaf, root and stolon. The distribution rate of dry matter of potato bud seedling treatment with different lengths was T1>T2>T3>CK. The distribution rates of tissues and organs of potato tuber, stem and leaf in T1 and T2 of the same variety were basically the same, with little difference, but significantly higher than T3 and CK treatment. In the T1 treatment cultivation of various varieties, the proportion of tubers was about 33%, and the proportion of stems and leaves was about 64%.

Among them, the proportion of ‘Zhongshu No. 4’ tubers was the highest (34.12%), and proportion of stems and leaves was 63.01%. The stem and leaf were in the main proportion in CK, and the highest proportion of ‘Youjin’ was 80.87%. The dry matter distribution rate of the potato in the tuber expansion stage under the cultivation of different parts of the potato buds was shown as the dry matter distribution rate of the tuber T4>T5>T6>CK. The 4 tested varieties showed the same performance, and the tuber stem of ‘Zhongshu 4’. The highest material distribution rate was 34.12%, and the lowest rate was found 16.30% for the direct seeding treatment of ‘Youjin’ bud block. The stem dry matter distribution rate and leaf dry matter distribution rate of each variety were the highest in CK (Fig. 2).

The comparison of physiological indexes of various experimental treatments in potato tuber expansion period showed that under the seedling raising level of potato bud nutrient bowl with different lengths, the chlorophyll content and photosynthetic indexes of potato plants in the same variety were the highest in T1 treatment, as followed by T2>T3 treatment, and the lowest was in CK. The maximum photosynthetic rate was 20.9% in ‘Feiwurita’ T1 treatment $\mu MolCO_2 \cdot m^{-2} \cdot s^{-1}$, the highest chlorophyll content was found in the T1 treatment of ‘Zhongshu 4’, which was 4.26 mg/g; Compared with potato seedling, the chlorophyll content of four tested varieties “Fujin, Youjin, Zhongshu 4 and Feiwuruita” increased at the utmost level, which were 32.97%, 49.57%, 51.06% and 37.93%, and the photosynthetic rate increased by 23.33%, 23.81%, 22.22% and 15.47% respectively (Table 9).

The research on physiological indexes of different parts of potato bud during the expansion period of potato tuber showed that there were significant differences in chlorophyll content, photosynthetic rate, and transpiration rate of other parts of potato sprouts during the tuber expansion period (Table 10). The photosynthetic rate and transpiration rate of potato during the expansion stage of potato tuber showed the order of T4> T5> T6> CK, and T4 and T5 were significantly different from T6 and CK, respectively. The performance trends of all varieties were seemed same. Among them, the chlorophyll content of ‘Zhongshu 4’ with the highest rate of 3.89mg/g, and highest photosynthetic rate of ‘Feiwurita’ is 20.1μmolCO^2•m^{-2}•s^{-1}. The stomatal conductance of different parts of tuber buds during expansion period was not obvious. The chlorophyll content of tuber top bud seedling treatment of ‘Zhongshu 4’. As compared with CK, the photosynthetic rate increased most obviously, increasing by 37.94% and 16.67%, respectively.

Effects of seedling cultivation methods on earliness and yield of potato

The planting date of each treatment was the same, and the harvest time and growth days in the shed were different. The earliest maturity among treatments in the same variety was T1, followed by T2, T3 and CK. Compared with the CK, T1 treatment could harvest 13 days in advance, and the difference of harvest days between T1 and T2 treatment is small, only 1-2 days (Table 11)

The yield composition of all tested potato varieties with different lengths of potato buds was as follows: in terms of average single potato weight and average plot yield, the difference between T1 and T2 was small, but it was significantly higher than T3 and CK. In terms of equivalent yield, T1>T2>T3>CK, the difference between T1 and T2 was not significant, but there was a significant difference from T3 and CK, respectively. The yield of each treatment increased by more than 10%. The T1 treatment of ‘Zhongshu 4’ had the highest yield of 3506.41kg/667m^2, and its relative yield increased by 46.35% (Table 12).

The effect of potato sprouts cultivation methods of different parts on potato yield All tested varieties showed as follows: Compared with CK, the average single potato weight and an average yield of different parts of potato buds were different (Table 13), of which T4 The average yield, average single potato weight and equivalent yield all reached the maximum, followed by T5, T6, and CK the lowest. Among them, the T4 treatment with the highest yield of ‘Eugene’ was 3,366.53 kg/667m^2. The relative yield increase was the most with the T4 treatment of ‘Feiwurita’, which increased the yield by 41.53%, the T6 treatment of each variety did not increase the yield significantly, ‘Zhongshu 4’ only increased production by 1.29%.

Effects of seedling cultivation methods on potato quality

The performance of post-harvest potato quality measurement of different length potato buds and different parts of potato buds in nutrient bowl cultivation was shown in Table 14 and 15. The measured values of reducing sugar, starch, crude protein, and L-Vc content between treatments in the same potato variety were shown the same without difference. However, there were significant differences in reducing sugar and crude protein among the tested varieties.There was no difference in starch determination between ‘Youjin’ and ‘Zhongshu 4’, but there were significant differences with ‘Fujin’ and ‘Feiwurita’ respectively. There was no difference in the content of L-Vc between 'Fujin' and 'Youjin', which was significantly different from ‘Zhongshu 4’ and ‘Feiwurita’ respectively. In terms of the commercial potato rate, the performance was T1> T2>T3>CK, T4>T5>T6>CK, and all tested varieties performed the same. In different lengths and different parts of the seedling experiment, the commercial potato variety that increased the most was the ‘Zhongshu 4’ variety. The 7cm seedlings increased by 5.4% compared with the control, and the top bud seedlings increased by 4.9% compared with the control.

Discussion

In the current study, bud planting method was used for cultivation of potato seedlings. The obtained results depicted that seedling cultivation improve the physiological indexes of potato plant growth, overall yield, and early maturity. Bud-seedling cultivation can significantly improve the yield of potato (Table 12 and Table 13), and the result is in consistent with early maturity and high yield in vegetable production (*Hai et al., 2015*). Potato bud-seedling cultivation makes a full use of main and auxiliary buds at each bud eye of the potato. It greatly increase the reproduction coefficient of potato, which is consistent with the previous research on increasing the utilization rate of seed potato by breaking seedling and transplanting technology for many times (*He, 1997; Li et al., 1994*).

In this study, a total of 4 potato varieties showed that different bud lengths of seedlings can shorten the sowing period, promote early maturity and harvest compared to the tuber seeding of potatoes (Table 12 and Table 13). Among the varietal treatments, T1 and T2 treatments exhibited the best performance. The main reason is that the bud seedling cultivation process takes a short time to grow seedlings, and the plants are grown in advance (*Fang, 2019*). The potato plant grows faster at the early stage, and underground root systems develop, resulting in larger leaf area, robust photosynthesis, more dry matter accumulation, and potential plant growth (*Zhou et al., 2014*). Potato plants can enter into the tuber swelling stage before time, then the tuber grows and develops in the ground for a long time, so the biological yield is high. At the same time, the temperature is lower at an early stage of tuber development, which is suitable for tuber growth. The large temperature difference between day and night is conducive to tubers’ expansion and the movement of stem and leaf assimilation to tubers (*Zhang, 2012*). Therefore, the yield of potato bud seedling cultivation is significantly higher than that of tuber seedling treatment.

Under the same management conditions, the measurement results of plant height and leaf number in the potato seedling stage (Table 3 and Table 5) are consistent with the standards of plant height of 5-10cm and 5-8 leaf numbers in seedling transplanting method (*Wang, 2009*). There was no significant difference in yield performance between 5cm potato bud seedling and 7cm potato bud seedling, but there was a significant difference in yield with 3cm potato bud, which was positively correlated with the growth and strength of potato bud (Table 12). At the seedling stage, some potato buds at the top of the potato grew robustly, which showed the highest level in terms of plant height, stem diameter and number of compound leaves (Table 3), and consistent with cultivation of strong buds based upon the principle of potato apical dominance, and yield of potato apical buds was the best (*Wen and Wang, 1993, Li, 2003*). The profile shows that young leaves of potato top bud start early and grow faster, the seedlings grow vigorously, and the yield is significantly increased, which is related to the early growth and development of plants the top advantage of top bud is obvious (*Wen and Wang, 1993*), while the number of leaves of potato middle bud, potato tail bud and control treatment decreases one by one, the growth potential decreases in turn, the leaf development time of young bud becomes later, and the growth rate slows down, It is consistent with potato tuber bud breaking propagation (*Xiao and Guo, 2007*).

At the same time, it is proved that young leaves of potato apical buds started early and grow faster, seedlings grew vigorously, apical dominance of apical buds was obvious, and the yield is increased significantly. It seems to be related to the growth and development of plants at early stage, while the number of leaves in potato middle bud, potato tail bud and control treatment decreased one by one, the growth potential decreases in turn, leaf spreading time of young bud becomes later, and growth rate slows down, which is consistent with the bud breaking propagation of potato tuber (*Xiao and Guo, 2007*).

In the various experimental treatments of potato bud seedling cultivation, the seedling cultivation management methods, fertilizer and water management during the growth period were consistent with those cultivated in a greenhouse. Therefore, there was no difference in quality between the treatments of various varieties. Still, there are also differences among different types of varieties, consistent with the performance of potato quality and varietal characteristics. In this current experiment, 5cm potato buds were selected for seedling cultivation, and obtained results showed that cultivation of seedling position of potato top buds was the best result. In short, three lengths of 3cm, 5cm and 7cm were selected as best in potato bud length test. There might be other suitable potato cultivation through various bud lengths or different parts of potato buds types having different lengths which needs to be further illustrated. In addition, the use of other proper and improper gradients of potato sprout lengths for seedling treatment is also requires further testing.

Conclusions

In this study, the potato bud planting method was used for the cultivation of seedlings. Potato buds with three different lengths (3cm, 5cm, and 7cm) were considered as T1, T2, T3 treatments, and terminal buds, middle buds, and tail buds were used as T4, T5, and T6 treatments, respectively. The obtained results depicted that plants' morphological and physiological growth indexes were significantly different among the treatments, and 5cm potato bud length treatment (T2) was proven as the best treatment for raising of seedlings and in line with actual requirements. Among the all tested varieties, T4 showed excellent growth, followed by T5, T6, and CK, during the seedling stage and all growth stages in the shed. There were also significant differences among the treatments of tested varieties during the determination of yield and commercial potato rate. Regarding the bud position treatments, the potato terminal bud was shown as the best treatment because the relative and commercial potato yield rates were the highest. In crux, we assumed that our proven bud planting technique should be adopted at commercial level which could help in good crop production with maximum yield.

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