https://doi.org/10.17221/45/2021-RAE

The effect of ethanol on potato growth and production at moderate elevation

Andi Muhibuddin[1], Zulkifli Maulana[1], Suryawati Salam[2], Syamsia Syamsia[3], Reta Reta[4], Arifin Fattah[5]*

[1]Department of Agrotechnology, Faculty of Agriculture, Bosowa University, Makassar, South Sulawesi, Indonesia
[2]Department of Social Economic, Faculty of Agriculture, Bosowa University, Makassar, South Sulawesi, Indonesia
[3]Department of Agrotechnology, Faculty of Agriculture, Muhammadiyah University, Makassar, South Sulawesi, Indonesia
[4]Department of Agroindustry, State Agricultural Polytechnic Pangkep, Pangkep, South Sulawesi, Indonesia
[5]Department of Social Economic, Faculty of Agriculture, Muhammadiyah University, Makassar, South Sulawesi, Indonesia

**Corresponding author: zulkifli.maulana@universitasbosowa.ac.id*

Citation: Muhibuddin A., Maulana Z., Salam S., Syamsia, Reta, Fattah A. (2022): The effect of ethanol on potato growth and production at moderate elevation. Res. Agr. Eng., 68: 113–119.

Abstract: Indonesia's current potato cultivation areas are mainly in the highlands (1 000 m above sea level – a.s.l.). However, there are obstacles to potato cultivation in the highlands, including erosion, declining land productivity, limited area, and high production costs (i.e. labour wages, fertilisers, and pesticides). This study was aimed at analysing the effects of both an ethanol application and moderate altitudes on the potato production and quality. This study was conducted at the Horticulture Seed Station in the Ulu Ere subdistrict, Bantaeng Regency, South Sulawesi, Indonesia. A split randomised plot design with two factors was used. The main plots were set at two elevation levels: 500 and 700 m a.s.l. The split plots were subjected to the addition of four ethanol concentration levels: 0, 10, 20, and 30%. The results showed that the ethanol application did not significantly affect the potato growth at the moderate elevation, except for the tuber diameter. Moreover, the 20% ethanol concentration produced better results than the 0% ethanol concentration. The application of 10% ethanol at an altitude of 700 m a.s.l. and 30% ethanol at an altitude of 500 m a.s.l. resulted in the best growth and yield among the studied treatments.

Keywords: CO_2 concentration; potato quality; Rubisco enzymes; split-plot design

Potatoes (*Solanum tuberosum* L.) are the fourth most important staple food after rice, wheat, and corn. They have high economic value and can be used as a rice substitute or processed into various types of food, including stews, chips, and fried foods. Potatoes are also useful for natural beauty and skin treatments (Camire et al. 2009). In Indonesia, the potato has always been cultivated in the highland areas, at 1 000–2 500 m above sea level (a.s.l.). High potato yields require low temperatures around 17–20 °C (Stark and Love 2003). The high altitude meets the optimum temperature of 18 °C for potato tuber formation (Acquaah 2012; Hancock et al. 2014).

https://doi.org/10.17221/45/2021-RAE

However, potato cultivation at 1 000 m a.s.l. is associated with several obstacles that decrease the productivity. Therefore, the cultivation development must be directed towards an expansion of 300–700 m a.s.l. to moderate elevations. Cultivating potatoes at moderate elevations requires overcoming the high-temperature issue, which stresses the potatoes (Stark and Love 2003) by causing rapid photorespiration (high CO_2 release), decreasing their photosynthesis (Zakaria 2010; Muhibuddin et al. 2017), and inhibiting the tuber growth (Rykaczewska 2015). Potatoes grown in high-temperature locations produce fewer tubers (Rykaczewska 2013; Muhibuddin et al. 2016) and exhibit morphological changes due to the inhibition of plant metabolic processes (Zakaria 2010; Muhibuddin et al. 2016; Muhibuddin et al. 2017).

Other problems in moderate elevation cultivation include a wider range of pests and diseases present at these elevations, especially bacterial wilt (*Pseudomonas solanacearum*), aphids (*Myzus persicae*), fusarium wilt (*Fusarium oxysporum*), and dry rot (*Alternaria solani*) (Stark and Love 2003). Yield loss due to pests is quite high, up to 20–40% of a loss in the yield and even 100% in certain areas.

High temperatures are one of the causes of the low productivity of potato plants at moderate elevations as they cause high photorespiration. Photorespiration causes the excessive release of CO_2, leading to a lower photosynthesis rate (Zakaria 2010). One method to increase the production of C3 plant groups, including potatoes, is to increase their photosynthesis rate by providing ethanol compounds as an additional treatment. Providing ethanol to C3 plants can increase their internal CO_2 concentration and reduce the transpiration rate (Zakaria 2010). Ethanol (C_2H_5OH) is a non-toxic, colourless, and tasteless solution, but has a distinctive odour being widely used as a solvent in the pharmaceutical, food, and beverage industries (Guo et al. 2014; Tadesse 2018).

This study aimed at determining the optimal ethanol concentration to enhance the growth and yield of Granola cultivar potatoes cultivated in moderate elevations.

MATERIAL AND METHODS

The study was conducted in the dry season from April to September 2018 at the Horticulture Seed Centre in the Ulu Ere subdistrict, Bantaeng Regency, South Sulawesi, Indonesia. The study used a split-plot design that allows for two factors in combination. They are recognised as the main plot and the split or subplot (Martins et al. 2018). The main plots were set in two moderate elevation levels, which were 500 and 700 m a.s.l. (referred to as H1 and H2, respectively). The subplots were subjected to four ethanol concentrations, namely, E0 = 0%, E1 = 10%, E2 = 20%, and E3 = 30% of ethanol. This crop split-plot design had three replications for 24 plots, and each plot had 20 plants. Five plants were measured as the samples for each plot.

Planting. The soil texture is a stable soil characteristic that affects the soil's physical and chemical properties. The soil particle size has a direct correlation with the particle's surface area (Zhao et al. 2011). This study used a sandy-loam soil – pH of 6.14 with 60% sand, 33% silt, and 7% clay). The soil organic matters were analysed as 7.38% carbon and 0.15% nitrogen, with a carbon to nitrogen ratio of around 49, 80 ppm of P_2O_5, and 6.0 ppm of K_2O. The land elevation (H1 and H2) had different day and night temperatures. Location H1 (500 m a.s.l.) had average day and night temperatures of 29.5 °C and 23 °C, respectively. Meanwhile, location H2 (700 m a.s.l.) had average day and night temperatures of 25.5 °C and 21.5 °C, respectively.

The soil was loosely prepared to a depth of 20–35 cm, smoothed, and left exposed to sunlight for one week. The land was cultivated for 24 plots of 1.6 m × 5 m for each plot. A basic fertiliser from chicken manure (20 $t \cdot ha^{-1}$) was applied 1 week before planting. A total of 1 000 $kg \cdot ha^{-1}$ of NPK [nitrogen, phosphorus, and potassium; 15-15-15 (%)] fertiliser was applied on the plots, half of it at the beginning of planting and the other half 1 month after planting, when weeding was performed. The Granola cultivar potato seeds were planted in prepared holes in the plots. The row spacing was 60 cm, and the plant spacing was 30 cm for the potato cultivation.

Ethanol application. Ethanol was sprayed on the surface of the potato leaves and potato stems two weeks after sowing (14 days after planting), then repeated at one-week intervals for 9 more weeks (77 days after planting) with one of the following doses: E0 (without ethanol, applied as a control); E1 (10% = 100 mL ethanol per 900 mL water); E2 (20% = 200 mL ethanol per 800 mL water); and E3 (30% = 300 mL ethanol per 700 mL water). The harvest occurred after the leaves began to dry or 90 days after planting.

https://doi.org/10.17221/45/2021-RAE

Data analysis. The data were statistically analysed using SPSS version 16 software (IBM, USA). The differences among the treatments were compared using an analysis of variance (ANOVA) with the least significant difference (LSD) post hoc comparison test at a 5% probability level.

RESULTS AND DISCUSSION

The ANOVA showed that the altitude had a significant effect on the height of potato plants at 30, 45, and 60 days after planting, while the ethanol application at various concentrations and the interaction of the elevation and the ethanol concentration had no significant effects (Table 1).

The LSD test showed that the H2 location produced a significantly wider stem diameter (0.93 cm) than the H1 one. Applying a 20% ethanol concentration (E2) produced the widest stem diameter at 45 days after planting (0.91 cm), which was significantly different from the stem diameter of E0, but not significantly different compared to E1 or E3. At 60 days after planting, H2 resulted in a significantly wider stem diameter (0.96 cm) than H1 (0.83 cm). The E2 ethanol treatment produced the highest tuber diameter (0.94 cm) at 60 days after planting, significantly different from E0, but not significantly different from E1 and E3 (Table 2).

Figure 1A shows that the relationship between the ethanol concentration (x) and the tuber diameter (y) at 45 days after planting exhibited a positive linear correlation at each altitude with the following Equations (1–2):

for H1: $y = 0.03x + 0.72$
$R^2 = 0.3488$ (not significant) (1)

Table 1. Plant height (cm) at 30, 45, and 60 days after planting with the elevation and ethanol treatments

Days after planting	Treatments	Elevation		Average
	ethanol	H1	H2	
30	E0	27.5	37.1	31.3[a]
	E1	33.0	45.8	39.4[b]
	E2	35.1	42.6	38.8[b]
	E3	33.1	39.5	36.3[ab]
	average	30.2[x]	40.8[y]	–
45	E0	42.7	59.6	51.1[a]
	E1	43.8	62.9	53.4[ab]
	E2	46.6	60.1	53.4[ab]
	E3	44.8	61.3	53.3[a]
	average	44.5[x]	61.0[y]	–
60	E0	46.9	62.9	54.9[a]
	E1	46.9	66.3	56.6[a]
	E2	49.3	64.8	57.1[ab]
	E3	48.0	63.6	55.8[a]
	average	47.8[x]	64.4[y]	–

Values followed by the same letter (a, b) are not significantly different according to the LSD test at α = 0.05. H1– cultivation at 500 m a.s.l.; H2 – cultivation at 700 m a.s.l.; E0 – control or without ethanol; E1 – 10% (100 mL ethanol per 900 mL water); E2 – 20% (200 mL ethanol per 800 mL water); E3 – 30% (300 mL ethanol per 700 mL water); x – ethanol (as the independent variable); y – yield (as the dependent variable)

for H2: $y = 0.022x + 0.87$
$R^2 = 0.5902$ (significant) (2)

Figure 1B shows that the relationship between the ethanol concentration (x) and the tuber diameter (y) at 60 days after planting also exhibited a positive

Table 2. Average stem diameter (cm) 45 and 60 days after planting

Time of observation	Elevation	Ethanol concentration				Average
		E0	E1	E2	E3	
45 days after planting	H1	0.72	0.79	0.88	0.79	0.80[x]
	H2	0.87	0.94	0.95	0.94	0.93[y]
	average	0.76[b]	0.86[a]	0.91[a]	0.86[a]	–
60 days after planting	H1	0.75	0.82	0.90	0.85	0.83[x]
	H2	0.91	0.97	0.99	0.97	0.96[y]
	average	0.83[b]	0.89[ab]	0.94[a]	0.91[a]	–

Values followed by the same letter (a, b) are not significantly different according to the LSD test at α = 0.05. H1 – cultivation at 500 m a.s.l.; H2 – cultivation at 700 m a.s.l.; E0 – control or without ethanol; E1 – 10% (100 mL ethanol per 900 mL water); E2 – 20% (200 mL ethanol per 800 mL water); E3 – 30% (300 mL ethanol per 700 mL water); x – ethanol (as the independent variable); y – yield (as the dependent variable)

https://doi.org/10.17221/45/2021-RAE

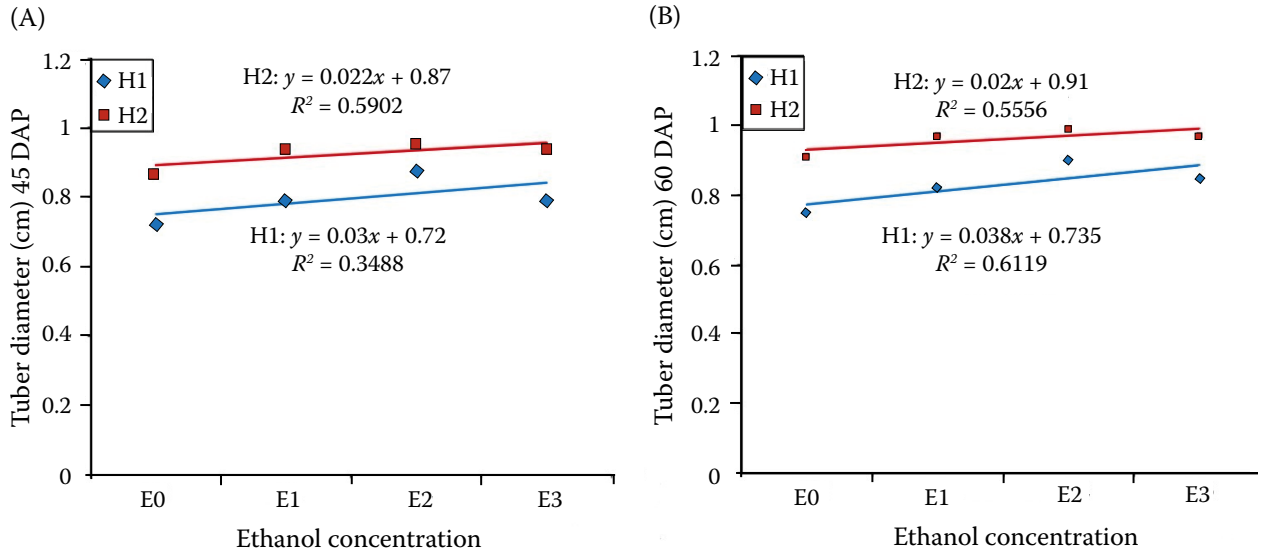

Figure 1. The relationship between the ethanol concentration and the tuber diameter at 45 (A) and 60 (B) days after planting

x – ethanol concentration; *y* – tuber diameter; DAP – days after planting; E0 – control or without ethanol; E1 – 10% (100 mL ethanol per 900 mL water); E2 – 20% (200 mL ethanol per 800 mL water); E3 – 30% (300 mL ethanol per 700 mL water)

linear correlation at each altitude with the following Equations (3–4):

for H1: $y = 0.038x + 0.735$ (3)
$R^2 = 0.6119$ (significant)

for H2: $y = 0.02x + 0.91$ (4)
$R^2 = 0.5556$ (significant)

The ANOVA showed that the elevation did not significantly affect the tuber diameter, nor did the interaction of the elevation and the ethanol concentration, while the treatment with the various ethanol concentrations had a significant effect. The LSD test results show that E1 and E2 had the widest tuber diameters (3.9 and 4.0 cm), which is significantly different from E0, but not E3 (Table 3).

The ANOVA test showed that the elevation significantly affected the final tuber weight, while the ethanol treatment had no significant effect. The LSD test results shown in Table 4 indicate that H2 produced a significantly heavier tuber weight (354 g) than H1. E3 produced the heaviest tuber weight (329 g), which is significantly different from E0 and E2, but not E1 (Table 4). Figure 2A shows the relationship between the ethanol concentration (*x*) and the tuber weight per plant (*y*), with a positive linear correlation at each elevation [Equations (5–6)].

Table 3. The average diameter of the tubers at harvest (cm)

Elevation	Ethanol concentration			
	E0	E1	E2	E3
H1	3.7	3.9	4.1	3.8
H2	3.4	3.9	4.0	3.8
Average	3.6^{b}	3.9^{a}	4.0	3.8^{ab}

Values followed by the same letter (a, b) are not significantly different according to the LSD test at α = 0.05. H1 – cultivation at 500 m a.s.l.; H2 – cultivation at 700 m a.s.l.; E0 – control or without ethanol; E1 – 10% (100 ml ethanol per 900 mL water); E2 – 20% (200 mL ethanol per 800 mL water); E3 – 30% (300 ml ethanol per 700 mL water)

Table 4. The average weight of the seed tubers (g) per plant at the end of the study

Tuber weight	Ethanol concentration				Average
	E0	E1	E2	E3	
H1	180	252	254	270	239^{x}
H2	303	404	320	388	354^{y}
Average	241^{c}	328^{a}	278^{b}	329^{a}	–

Values followed by the same letter (a, b, c) are not significantly different according to the LSD test at α = 0.05. H1 – cultivation at 500 m a.s.l.; H2 – cultivation at 700 m a.s.l.; E0 – control or without ethanol; E1 – 10% (100 mL ethanol per 900 mL water); E2 – 20% (200 mL ethanol per 800 mL water); E3 – 30% (300 mL ethanol per 700 ml water); *x* – ethanol concentration (as the independent variable); *y* – yield (as the dependent variable)

https://doi.org/10.17221/45/2021-RAE

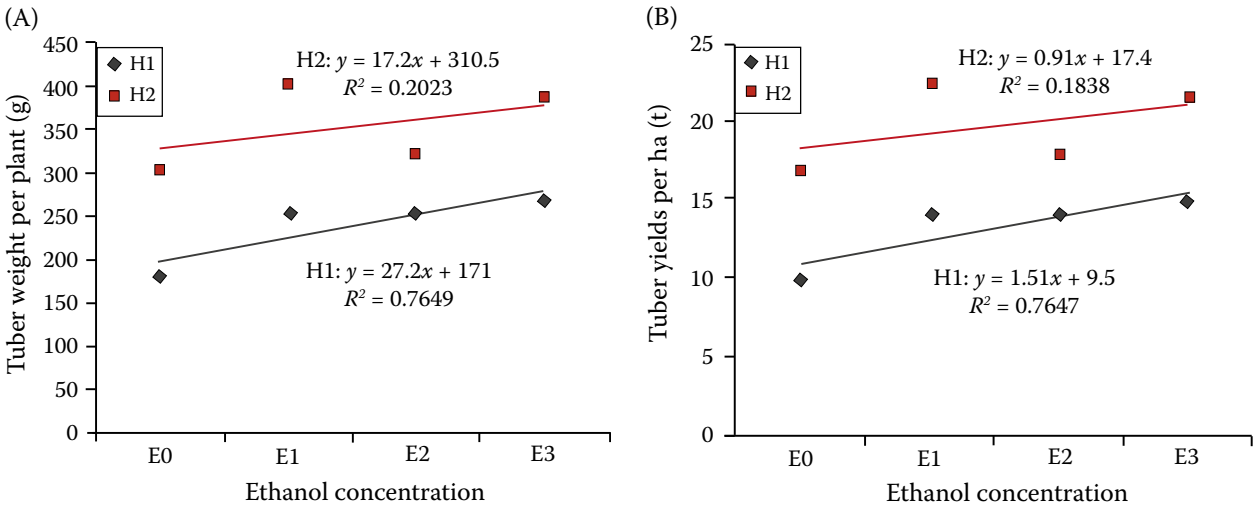

Figure 2. The relationships between the ethanol concentration and tuber weight per plant (A) and tuber yields per ha (B) at H1 and H2

x – ethanol concentration; *y* – tuber weight per plant and tuber yield per ha, respectively; E0 – control or without ethanol; E1 – 10% (100 mL ethanol per 900 mL water); E2 – 20% (200 mL ethanol per 800 mL water); E3 – 30% (300 mL ethanol per 700 mL water)

for H1: $y = 27.2x + 171$
$R^2 = 0.7649$ (highly significant) (5)

for H2: $y = 17.2x + 310.5$
$R^2 = 0.2023$ (not significant) (6)

The ANOVA test showed that both the elevation and ethanol concentration had significant effects on the tuber yield per hectare. The LSD test shown in Table 5 indicated that H2 resulted in a significantly higher tuber yield (19.7 t·ha^{-1}) than H1 (13.3 t·ha^{-1}). E2 produced a significantly higher yield (19.8 t·ha^{-1}) than E0. However, it was not significantly different from the E1 or E3 treatments. Figure 2B shows the relationship between the ethanol concentration (*x*) and the tuber yield per ha (*y*), with a positive linear correlation at each altitude, described by the following Equations (7–8):

for H1: $y = 1.51x + 9.5$
$R^2 = 0.7647$ (highly significant) (7)

for H2: $y = 0.91x + 17.4$
$R^2 = 0.1838$ (not significant) (8)

Table 5. Tuber yield (t·ha^{-1}) at harvest

Tuber yield (t·ha^{-1})	Ethanol concentration				Average
	E0	E1	E2	E3	
H1	10.0	14.0	14.1	15.0	13.3^{x}
H2	16.9	22.5	17.8	21.5	19.7^{y}
Average	13.5^{b}	18.3^{a}	19.8^{a}	18.3^{a}	–

Values followed by the same letter are not significantly different according to the LSD test at α = 0.05. H1 – cultivation at 500 m a.s.l.; H2 – cultivation at 700 m a.s.l.; E0 – control or without ethanol; E1 – 10% (100 mL ethanol per 900 mL water); E2 – 20% (200 mL ethanol per 800 mL water); E3 – 30% (300 mL ethanol per 700 mL water); *x* – ethanol (as the independent variable); *y* – yield (as the dependent variable)

The results indicate that the cultivation at two different elevations had a significant effect on the growth parameters, which were the plant height at 30, 45, and 60 days after planting and the stem diameter at 45 and 60 days after planting. Cultivation at H2 produced the tallest plants and the largest tuber diameter (Table 1 and Table 2). This is because the elevation on the potato plants' physiological activity, especially photosynthesis. Potato plants with temperature stress have reduced growth (Harjadi and Yahya 1998; Zakaria 2010).

The 10% ethanol treatment at H2 and 20% at H1 tended to produce the tallest plants compared to the other treatment combinations. This is because the ethanol sprayed on the potato plants will be decomposed in the leaf mesophyll into CO_2, increasing the CO_2 concentration in the leaf mesophyll. Thus, the CO_2 to O_2 ratio increases. The increasing CO_2 to O_2 ratio increases the photosynthesis and decreases the photorespiration rate. This is related to previous studies (Hagemann and Bauwe 2017;

https://doi.org/10.17221/45/2021-RAE

Taiz et al. 2018) where it was that photorespiration occurs due to the decrease in the CO_2 concentration, while the O_2 concentration increases in the leaf mesophyll. According to Zakaria (2010), increasing the CO_2 concentration and suppression of the O_2 concentration in the leaf mesophyll will cause the O_2 to be less competitive with the CO_2 in obtaining ribulose 1,5-bisphosphate carboxylase-oxygenase (Rubisco) enzymes and Ribulose 1,5-bisphosphate (RuBP) substrates, thus benefiting the RuBP carboxylase compared to the RuBP oxygenation.

All the ethanol treatments (10, 20, and 30%) resulted in an increased tuber diameter over the control (Table 2). This is presumably a result of the CO_2 contribution from the ethanol, which causes an increase in the photosynthetic rate of potato plants, thus increasing the amount of assimilation to actively growing tissue to support the growth, including the stem diameter growth.

The LSD test (Table 2 and Table 3) showed that E2 tended to produce higher tuber diameters compared to E0 and E1, while E3 showed a decrease in diameter. The tuber formation process is a continuation of the stolon formation process, starting from the tuber formation and followed by the assimilate storage until the tubers reach a certain number and size (Kolachevskaya et al. 2019). According to Kim and Lee (2019), when the development of tubers begins, the CO_2 assimilation increases three times compared to when the tuber has not been formed. The translocated assimilation into the tubers can reach twice the amount of the assimilates used by plant parts above the roots. The highest tuber weight was obtained from E3, which had the highest ethanol concentration.

The only significant difference observed in the tuber yield was between the elevations. Taiz et al. (2018) stated that photorespiration occurs because the CO_2 concentration decreases and the O_2 concentration increases in the leaf mesophyll. Thus, an increase in the CO_2 concentration and suppression of the O_2 concentrations in the leaf mesophyll causes the O_2 to be unable to compete with the CO_2 in obtaining Rubisco enzymes and RuBP substrate, which affects the occurrence of the RuBP carboxylation compared to the RuBP oxygenation. The benefits of increasing the CO_2 concentration include a combination of several physiological effects that increase the crop production. The increased CO_2 in C3 plants increases the amount of photosynthesis, the net rate of the photosynthesis (Muhibuddin et al. 2018), the internal carbon transformation (Ruan et al. 2012), and the optimal leaf temperature tolerance, which results in an increased photosynthesis net (Saravia et al. 2016).

The tuber weight and yield were the highest in E2 due to its effects on the photosynthesis, respiration, and translocation processes. Glucose, which is formed from the net results of the photosynthesis, is converted into fructose or sucrose. Sucrose is then transported into the enlarged cell wall and is transformed into a structural component such as cellulose. The distribution of assimilates to each tuber is determined by the capacity of the tubers to compete to obtain the assimilates from the leaves, and the number and diameter of tubers influence the tuber weight during the growth of the potato plant (Suharjo and Catur 2010).

The tuber yield per ha increased in response to the 30% ethanol treatment, in line with the expected increase in the number of tubers, diameter, and weight due to the high rate of photosynthesis from the increased internal CO_2 in the leaf mesophyll. The potato production increases per the increase in the photosynthesis rate. This is in line with Taiz et al. (2018) statement that the ability of plants to carry out photosynthesis will determine the amount of accumulated plant assimilates in the form of tubers.

The ability of a potato plant to photosynthesise determines its production. This fact is reflected in an increase in the plant height, stem diameter, tuber diameter, tuber weight per plant, and tuber yield per ha observed in this study with each increase in the ethanol concentration from 0% to 20%. However, there was a downward trend at the 30% concentration, though it was not significant. This may have occurred because the 30% ethanol treatment caused the potato plants to experience CO_2 saturation so that their physiological activity, growth, and production were inhibited.

CONCLUSION

This study revealed that a foliar ethanol application at different concentrations did not significantly affect the potato growth or yield except for the tuber diameter, for which the 20% ethanol concentration yielded better results. The cultivation at 700 m a.s.l. resulted in better growth and yield compared to 500 m a.s.l. There was no interaction between the elevation and the ethanol concentration on the growth and yield of the potato crops cultivated at moderate elevations.

https://doi.org/10.17221/45/2021-RAE

REFERENCES

Acquaah G. (2012): Principles of Plant Genetics and Breeding. Hoboken: John Wiley & Sons, Ltd.

Camire M.E., Kubow S., Donnelly D.J. (2009): Potatoes and human health. Critical Reviews in Food Science and Nutrition, 49: 823–840.

Guo M., Littlewood J., Joyce J., Murphy R. (2014): The environmental profile of bioethanol produced from current and potential future poplar feedstocks in the EU. Green Chemistry, 16: 4680–4695.

Hagemann M., Bauwe H. (2017): Photorespiration. In: Thomas B., Murray B.G., Murphy D.J. (eds): Encyclopedia of Applied Plant Sciences. 2nd Ed. Cambridge, Academic Press: 86–89.

Hancock R.D., Morris W.L., Ducreux L.J., Morris J.A., Usman M., Verrall S.R., Fuller J., Simpson C.G., Zhang R., Hedley P.E., Taylor M.A. (2014): Physiological, biochemical and molecular responses of the potato (*Solanum tuberosum* L.) plant to moderately elevated temperature. Plant, Cell & Environment, 37: 439–450.

Harjadi S.S., Yahya S. (1998): Fisiologi Stress Tanaman. Bogor: PAU IPB (in Indonesian).

Kim Y.U., Lee B.W. (2019): Differential mechanisms of potato yield loss induced by high day and night temperatures during tuber initiation and bulking: Photosynthesis and tuber growth. Frontiers in Plant Science, 10: 300.

Kolachevskaya O.O., Lomin S.N., Arkhipov D.V., Romanov G.A. (2019): Auxins in potato: Molecular aspects and emerging roles in tuber formation and stress resistance. Plant Cell Reports, 38: 681–698.

Martins J.D.L., Soratto R.P., Fernandes A.M., Dias P.H.M. (2018): Phosphorus fertilization and soil texture affect potato yield. Revista Caatinga, 31: 541–550.

Muhibuddin A., Razak Z., Salam S., Boling J. (2016): Development of potato plants as the results of aeroponic technology by treating of methanol in plain medium at Ulu Ere subdistrict, Bantaeng Regency, South Sulawesi, Indonesia. International Journal of Current Research and Academic Review, 4: 140–148.

Muhibuddin A., Salam S., Razak Z., Boling J. (2017): The yield response and quality of potato as aeroponics technology results towards methanol and *Gliricidia sepium* leaf extract in medium plain. Advances in Environmental Biology, 11: 1–9.

Muhibuddin A., Razak Z., Salam S., Syamsia, Boling J. (2018): Nutrients formulation for improving production and quality of potato minitubers using aeroponic system in Indonesia. Advances in Environmental Biology, 12: 38–42.

Ruan C.J., Shao H.B., Teixeira da Silva J.A. (2012): A critical review on the improvement of photosynthetic carbon assimilation in C3 plants using genetic engineering. Critical Reviews in Biotechnology, 32: 1–21.

Rykaczewska K. (2013): The impact of high temperature during growing season on potato cultivars with different response to environmental stresses. American Journal of Plant Sciences, 4: 2386–2393.

Rykaczewska K. (2015): The effect of high temperature occurring in subsequent stages of plant development on potato yield and tuber physiological defects. American Journal of Potato Research, 92: 339–349.

Saravia D., Farfán-Vignolo E.R., Gutiérrez R., Gutierrez R., De Mendiburu F., Schafleitner R., Bonierbale M., Khan M.A. (2016): Yield and physiological response of potatoes indicate different strategies to cope with drought stress and nitrogen fertilization. American Journal of Potato Research, 93: 288–295.

Stark J.C., Love S.L. (2003): Potato Production Systems. Moscow: University of Idaho.

Suharjo U.K.J., Catur H. (2010): Performance of gamma-irradiated potato cv. Atlantic and granola grown under medium elevation (600 m a.s.l.) in Bengkulu. Akta Agrosia, 13: 82–88.

Tadesse T. (2018): Extraction and characterization of ethanol obtained from potato in Tepi Town local market. Open Access Journal of Chemistry, 2: 17–24.

Taiz L., Zeiger E., Møller I.M., Murphy A. (2018): Fundamentals of Plant Physiology. Oxford: Oxford University Press.

Zakaria B. (2010): Stimulants CO_2 on Photosynthesis and Plant Stress. Makassar: Kretakufa Print.

Zhao P., Shao M.A., Omran W., Amer A.M. (2011): Effects of erosion and deposition on particle size distribution of deposited farmland soils on the chinese loess plateau. Revista Brasileira de Ciência do Solo, 35: 2135–2144.

Received: May 25, 2021
Accepted: December 3, 2021
Published online: May 30, 2022