

Response of Potato Crops Grown at Medium Altitude to Gamma Rays Irradiation and CCC Application

Usman Kris Joko Suharjo^{*1}, Catur Herison¹, Tunjung Pamekas²

¹*Department of Agronomy, College of Agriculture, Bengkulu University,
Jl. W.R. Supratman, Bengkulu City 39371, Bengkulu, Indonesia.*

²*Department of Plant Protection, College of Agriculture, Bengkulu University,
Jl. W.R. Supratman, Bengkulu City 39371, Bengkulu, Indonesia.*

*Corresponding author: usman_maine@yahoo.com¹

Abstract

Growing crops at medium elevation in Indonesia may face problems related to high temperature, which inhibits tuber formation and growth, resulting in lower number and smaller size of tuber. It might be overcome by planting heat-tolerant cultivars and/or providing a package of technology suitable for the area. In this respect, greenhouse experiments to evaluate the effects of gamma rays (0, 30, 60 Gy) and CCC (0, 600 ppm) on crop growth and tuber production were conducted. Potato seeds were irradiated by gamma rays, planted in polybag filled with 10 kg of sterile media, a mixture of top soil and manure (4:1, v/v), and sprayed with either CCC or TPS. The crop growth and tuber production were observed. The results showed that 60 Gy delayed tuber emergence, killed most of the seeds planted, reduced tuber formation, and inhibited tuber growth. In contrast, 30 Gy promoted crop growth and tuber production. The application of CCC significantly inhibited crop growth, but did not promote tuberization. There was no significant interaction between gamma rays irradiation and CCC or TPS on affecting crop growth. However, the interaction significantly affected potato yield components. We concluded that the best gamma ray irradiation for potato seeds was 30 Gy. Higher dosage was detrimental, reducing plant growth, and yield.

Keywords: *growth retardant; heat tolerance; medium elevation; potato growth and yield; seed irradiation.*

Introduction

Attempt to bring potato crops to lower elevations in Indonesia is very challenging due to the warm climate (Suharjo *et al.*, 2012), since potato crops are well-known to be very sensitive to high temperature (Rykacewska, 2013), and need average temperature of 17-20 °C to grow well and produce lots of tubers (Stark and Love, 2003). At high temperature potato crop produce less tubers because of the increase in GA3 biosynthesis at the axillary bud of the potato crops [6]. In addition, high temperature also promotes night respiration (Taiz and Zeiger, 2005) results in the smaller size of potato tubers (Manrique *et al.*, 1989). In short, growing potato crops at medium or low elevation may produce less number of tuber and/or smaller size of tuber. To overcome these problems, one may take two major approaches, which are crafting a package of technology suitable for the area and/or finding new clones of potato tolerant to heat stress.

Suharjo *et al.* (2008) have started to craft a suitable technology for growing potato crops at medium elevation by studying the effects of growth retardants (Ancymidol, Paclobutrazol, CCC, and Coumarin) on potato formation at high temperature *in vitro*. We found that at 35/28 °C (day/night) the effective concentration of growth retardant to promote tuber formation were 4 ppm Ancymidol, 50 ppm Coumarin, 4000 ppm Paclobutrazol, and 1200 ppm CCC. The 35/28 °C was used to mimic the daily temperature of low elevation in Indonesia. These findings need to be followed up with greenhouse or field experiments. In this experiment the authors choose to use CCC and newly formulated Tuber Promoting Substances (TPS) to promote tuber formation in potato crop at medium elevation. The CCC and TPS were applied to the crop by spraying them directly to the plants. Similar method had also been done by Pavlista (2013).

The other approach needed to explore is by crafting a new clone adaptive to medium elevation, which might be done by various breeding programs, like introduction, selection, hybridization, and mutation (Cheng *et al.*, 2010; Suharjo *et al.*, 2010a). In addition to naturally induced mutation, one might artificially induced mutation by applying some chemical compound or by physical force, like gamma ray radiation (Cheng *et al.*, 2010). After radiating potato tuber seeds with 0, 30, and 60 Gy of gamma rays, Suharjo *et al.*, 2010a reported that high dose (60 Gy) of radiation resulted in the delayed crop emergence, killed almost all tuber planted, and reduced crop ability to produce tuber. At 30 Gy, however, radiation promote plant growth and tuber production. Similar results was also found by Cheng *et al.* (2010). It was (Cheng *et al.*, 2010) reported that compared to the control treatment (no radiation), gamma rays radiation delayed crop emergence up to 10-15 days. While low dose of radiation (10-30 Gy) promoted plant growth and tuber formation, no crop emergence was found at 60 Gy and higher dose. It was also reported that after radiation, a series of morphological variations and chromosome aberrations appeared in the plants.

In this experiment, the authors wish to combine the effect of gamma ray radiation and the application of growth retardant (CCC) or Tuber Promoting Substance (TPS) on potato crop growth and tuber production. Considering the daily temperature at medium elevation was expected to be much lower than that of low elevation (Suharjo *et al.*, 2010), the author decided to reduce the CCC concentration to 600 ppm, instead of 1200 ppm used for high temperature (Suharjo *et al.*, 2008).

For these reasons, a series of experiments were conducted in two years at different location of medium elevations. The objective of these experiments were: (1) to evaluate the effects of gamma radiation on crop growth and production at medium elevation, hoping that a candidate of a new clone might be found for medium elevation, (2) to evaluate the effects of growth retardant on potato crop growth and production at medium elevation, hoping that a new method for promoting tuber formation at medium elevation would be materialized, (3) to evaluate effects of Tuber Promoting Substances on potato crop growth and tuber production, and (4) to evaluate the effects of combined treatments among these three factors. The expected out from this experiment were a candidate high yielding clone and a package of technology suitable for the medium elevation.

Research Method

Two experiments were carried out at the plastic house of Bengkulu University Experimental Station, located at 600 m above sea level (asl) either in the District of Kepahiang in 2010 or in the District of North Bengkulu in 2013 to study the effect of gamma ray irradiation and CCC application on the growth and yield of potato crops. The experiment was arranged in Completely Randomized Design (CRD) with 2 factors and 5 replications. The first factor tested was gamma ray irradiation (R), consisting of $R_0 = 0$ Gy, $R_1 = 30$ Gy, and $R_2 = 60$ Gy. The second factor was concentration of CCC (C), consisting of $C_0 = 0$ ppm and $C_1 = 600$ ppm.

Media Preparation. Media preparation for both experiments were the same. Top soil and manures were mixed by 4:1 ratios (v/v), spreaded on the ground on top of plastic sheet, and sprayed with 4% of formalin solution until got wet. The media were covered with plastic sheet for 2 weeks to give the formalin solution enough time to kills all of the soil microorganisms. After 2 weeks of incubation, the plastic covered was removed and the media (10 kg each) were dispensed into polybags. The media were ready for growing potato crops.

Seed Preparation. This was applied for both experiments. Potato seed tubers (20 g each) were irradiated by gamma rays at different levels of radiation (0, 30, and 60 Gy) at the National Atomic Energy Board (Badan Tenaga Atom National, BATAN) in Jakarta.

Planting, Maintenance, and Harvesting. Seed tubers were planted in the polybag, 1 seed (20 g) of each polybag. At planting, the crops were fertilized with Urea (400 kg Ha^{-1}), KCl (150 kg Ha^{-1}), and TSP (300 kg Ha^{-1}). The crops were sprayed with 2 g L^{-1} of Agrept 30 WP and 2 g L^{-1} Dithane M-45 every 7 days. The tubers were harvested when the fine start dying.

Variable measured. Plant growth (plant height, leaf number, node number) was measured, with some additional of plant emergence and plant survival for gamma ray irradiation treatment. Tuber yield components (stolon number, tuber number, tuber weight, and tuber diameter) were observed after harvest. The data were analyzed with analysis of variance (ANOVA) and mean comparison by Duncan's Multiple Range Test (DMRT) at $\alpha = 5\%$.

Results and Discussion

Effect of Gamma Rays Irradiation

The gamma rays irradiation (0, 30, 60 Gy) on potato seeds significantly affected all variables measured, except for leaf number (Table 1) and diameter of the smallest tuber (Table 2). For both years, gamma rays delayed time for crops to emerge and reduced the percentage of crop emergence. The negative effects of gamma rays were more pronounced at higher dosage (60 Gy) which killed almost 53% of the crops in 2010 and 74% in 2013. In addition, only 16% (in 2010) and 17% (in 2013) of the emerging crops managed to survive and produced tubers. These findings confirmed a previous study reported by the author [10]. After irradiating potato seeds c.v. Granola and Atlantic with 0, 30, and 60 Gy gamma rays and grew them at medium elevation, Suharjo *et al.* (2008) found that 60 Gy of gamma rays significantly inhibited crop growth and killed almost all of the seeds planted.

Table 1. Effects of gamma-ray irradiation on potato crop growth.

Variable measured	Experiment 1			Experiment 2		
	0 Gy	30 Gy	60 Gy	0 Gy	30 Gy	60 Gy
Time to emerge (days)	20.2 a	35.7 b	57.2 c	12.5 a	23.4 b	34.6 c
Crop emergence (%)	100,0 a	100.0 a	46.7 b	100.0 a	100.0 a	35,7 b
Crop survival (%)	100.0 a	96.7 a	16.7 b	100.0 a	100.0 a	17.8 b
Plant height (cm)	45.7 b	63.9 a	60.7 a	39.2 ab	43.9 a	37.4 b
Node number	15.5 b	18.2 a	16.6 ab	15.1 ab	16.9 a	13.6 b
Leaf number	14.5 a	16.7 a	14.6 a	29.8 a	30.5 a	20.4 a

Remark: number followed by the same letter at the same row for the same experiment were not significantly different according to DMRT $\alpha = 5\%$

In this experiment, 60 Gy produced the lowest number of tuber while the control treatment (0 Gy) produced the highest number of tuber (Table 2). These results were different from those reported by Suharjo *et al.* (2010a) who found that 30 Gy resulted in the highest number of tuber, ranging from 7.4 -22.7 tubers when potato seeds were irradiated with 0, 30, and 60 Gy Gamma rays. It showed that low dosage of gamma irradiation promote growth and crop yield which might cause by the duplication, inversion, and translocation of chromosome (Ismachin, 1988).

Table 2. Effects of gamma rays irradiation on tuber yield component for two years of experiment.

Variable measured	Experiment 1			Experiment 2		
	0 Gy	30 Gy	60 Gy	0 Gy	30 Gy	60 Gy
Tuber number per plant (#)	7.4 a	7.1 a	3.2 b	8.8 a	7.5ab	5.3b
Stolon productive (%)	81.6 a	79.6 a	59.6 b	91.2 a	82.5 b	81.2 b
Tuber fresh weight (g)	83.7 a	65.5 b	26.8 c	84.7 a	38.9 b	29.5 b
Diameter of largest tuber (mm)	26.9 a	25.8 a	19.7 b	28.9 a	26.1 a	17.7 b
Diameter of smallest tuber (mm)	13.6	13.1	14.9	14.1	14.0	7.2

Remark: number followed by the same letter at the esame row for the experiment were not significantly different according to DMRT $\alpha = 5\%$

Effects of Growth Retardant

Compared to the control treatment (0 ppm CCC), growth retardant (600 ppm CCC) significantly reduced crop growth, shown by lower plant height and shoot dry weight (Table 3). These results suggested that the growth retardant (CCC) used for the experiment was still effective, considering that plant height and crop dry matter are good indicators for measuring crop growth (Taiz and Zeiger, 2005). At higher concentration (1200 ppm), CCC severely suppressed plant growth so that the shoot of potato crops reached only 8 cm (Suharjo, 2010). These results confirmed that CCC is a growth retardant, known as an anti-GA compound (Menzel, 1980), whose function is to inhibit crop growth. If there was no significant effects of 600 ppm CCC on node and leaf number this was because in this experiment the retardant was applied only once

when the crops were 3 weeks old after emergence, in addition to its low concentration (600 ppm). When applied at earlier growth stage or at higher concentration (Suharjo, 2010b) the growth retardant showed significant growth suppressions.

Table 3. Effect of retardant (CCC) on plant growth

Treatments	Plant height (cm)		Node number(#)		Leaf number (g)		Shoot dry weight (g)	
	Exp. 1	Exp. 2	Exp.1	Exp. 2	Exp. 1	Exp.2	Exp. 1	Exp. 2
Retardant (CCC)								
0 ppm	59.1 a	62.1 a	16.9 a	21.0 a	15.4 a	18.9 a	158,9 a	172.2 a
600 ppm	50.6 b	51.9 b	16.6 a	20.4 a	15.4 a	18.3 a	143,7 b	154.9 b

Remark: number followed by the same letter at the same column for the same treatment and experiment were not significantly different according to LSD $\alpha = 5\%$

Table 4. Effect of retardant (CCC) on plant growth

Treatments	Stolon number		Tuber number		Tuber weight (g)		Tuber diameter (mm)	
	Exp. 1	Exp. 2	Exp.1	Exp. 2	Exp. 1	Exp.2	Exp. 1	Exp. 2
Retardant (CCC)								
0 ppm	6.6 a	7.6 a	5.1 a	5.3 a	52.6 a	54.2 a	22.1 a	22.6 a
600 ppm	6.3 a	6.2 b	6.2 b	6.3 b	49.2 a	62.8 b	23.2 b	25.1 b

Remark: number followed by the same letter at the same column for the same treatment and experiment were not significantly different according to LSD $\alpha = 5\%$ 6.6

Interaction Effect of Gamma Rays and Growth Retardant

It was likely that the effect of gamma rays (0, 30, 60 Gy) on crop growth was independent from those of growth retardant (0, 60 ppm CCC), since no significant interaction effect between them were found (data were not presented). However, the combination of the two treatments showed significant interaction on yield component, such as tuber number, tuber weight, and tuber diameter (Table 5).

At this point, the author did not have information on which factor was more dominant than the other even though the data suggested that gamma rays was more dominant than growth retardant. However, the data suggested that the combination of 30 Gy with either 0 or 600 ppm CCC was more superior than that of 60 Gy with either 0 or 600 CCC (Table 5). It was likely that the effect of gamma irradiation was more pronounced than that of growth retardant. At high temperature, like at low elevation of hot tropical Bengkulu, potato crops produce lots of GA3, which inhibits potato tuber formation (Menzel, 1982). Eliminating the source of GA3 by removing the axillar buds or eliminating the negative effect of GA3 by spraying growth retardant, known as anti-GA, resulted in the tuber production (Menzel, 1983). However, Purnamasari (2010) reported that, at medium elevation of Bengkulu, eliminating the axillar buds or spraying 600 ppm CCC did not let the crops produce more tubers than the Control treatments (No bud removal and/or No retardant application), suggesting that at medium elevation the GA3 biosynthesis was not high enough to prevent tuberization. It therefore did not need

growth retardant (600 CCC) to suppress GA3 effects. These what might take place in this current experiment that explain why the application of 600 CCC did not show tremendous effect on tuberization.

Table 5. Effect of gamma-ray irradiation and retardant (CCC) on potato yield component

Treatments	Stolon number (#)		Tuber number (#)		Tuber weight (g)		Tuber diameter (mm) ¹⁾	
	Exp. 1	Exp.2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
0 Gy Gamma Rays								
0 ppm CCC	8.3 a	9.5 a	6.2 ab	7.2 a	82.7 a	67.5 ab	26.6 a	25.7 ab
600 ppm CCC	8.2 a	7.9 a	7.3 a	6.7 ab	84.6 a	78.1 a	27.2 a	28.1 a
30 Gy Gamma Rays								
0 ppm CCC	7.3 a	8.1 a	6.5 ab	7.1 a	69.7 ab	74.6 a	25.5 a	27.1 a
600 ppm CCC	6.7 a	7.2 a	7.8 a	7.9 a	61.4 ab	77.8 a	26.2 a	29.0 a
60 Gy Gamma Rays								
0 ppm CCC	5.0 a	6.2 a	3.0 b	2.3 b	7.0 c	21.1 c	14.7 a	16.1 c
600 ppm CCC	5.8 a	5.9 a	3.3 b	3.6 b	4.0 c	32.6 c	18.6 a	19.2 c

Remark: number followed by the same letter at the same column for the same year were not significantly different according to LSD $\alpha = 5\%$

Conclusion

We concluded that the application of either CCC significantly inhibited crop growth, but did not promote tuberization. Furthermore, the best gamma ray irradiation for potato seeds was 30 Gy. Finally, the interaction between gamma ray irradiation and CCC significantly affected potato yield components, in which the best interaction was found in 30 Gy with 600 ppm CCC.

Acknowledgments

These research were partly funded by the DGHE, the Minister of Education, Republic of Indonesia in 2010, awarding Usman K.J. Suharjo the grant. The authors offer their gratitude to Aan for his field works

References

- Cheng, L., H. Yang, B. Lin, Y. Wang, W. Li, and F. Zhang. (2010). Effect of gamma-say radiation on physiological, morphological characters and chromosome aberration of minitubers in *Solanum tuberosum* L. *Int. J. Radiato. Biol.* 86(9): 791-799. Doi: 10.3109/09553002.2010.484478.
- Ismachin, M. (1988). Pemuliaan Tanaman dengan Mutasi Buatan. Pusat Aplikasi Isotop dan Radiasi. Badan Tenaga Atom Nasional. Jakarta.
- Kusumawati, L. (2006). Pertumbuhan dan Pembentukan Umbi Mikro secara *in Vitro* dengan Pemberian 5 Kosentrasi Chlorocholine Chloride (CCC) pada Dua Suhu Inkubasi (18 dan 25 °C). Skripsi Jurusan Budidaya Pertanian, Fakultas Pertanian UNIB (tidak dipublikasikan).
- Manrique, L.A., D.P. Bartholomew, and E.E. Ewing. (1989). Growth and yield performance of several of several potato clones grown at three elevatin in Hawaii. I. *Plant Morphology. Crop Sci.* 29: 663-370.
- Mattjik, N.A. (2016). Komposisi Zat Pengatur Tumbuh untuk Meningkatkan Produksi Umbi Mini Kentang. Paten Nomor: S0020000206 (ID S0000412). <http://repository.ipb.ac.id/handle/123456789/4116>. Diakses 10 Desember 2016.
- Menzel, C.M. (1980). Tuberization in potato at high temperature: responses to gibberrellin and growth inhibitors. *Annal of Botany* 46: 259-265.
- Pavlista, A.D. (2013). Influence of Foliar-Applied Growth Retardants on Russet Burbank Potato Tuber Production. *Am. J. Potato Res.* 90: 395-401.
- Purnamasari, O. (2010). Pembuangan Tunas Aksilar dan Aplikasi CCC untuk memacu pembentukan umbi kentang di dataran medium. Skripsi Jurusan Budidaya Tanaman, Fakultas Pertanian UNIB (*unpublished*).
- Rykacewska, K. (2013). The impact of high temperature during growing season on potato cultivars with different response to environmental scstress. *Amer. J. Plant Sci.* 4: 2836-2393
- Stark, J.C. and S.L. Love. (2003). *Potato Production Systems: a comprehensive guide for potato production*. University of Idaho Extension. Idaho, USA. 426 pages.
- Suharjo, U.K.J., Fahrurrozi, and S. Sudjatmiko. 2008. Memacu pembentukan umbi mikro tanaman kentang yang ditanam secara *in vitro* pada suhu tinggi dengan aplikasi Ancymidol, Paclobutrazol, CCC, dan Coumarin. *Prosiding Seminar Nasional Pekan Kentang 2008*. Departemen Pertanian, Lembang, pp: 75-88. ISBN 978-979-8257-35-3.
- Suharjo, U.K.J., C. Herison, and Fahrurrozi. (2010a). Keragaan tanaman kentang varitas Atlantik dan Granola di dataran medium (600 m dpl) Bengkulu pasca iradiasi sinar gamma. *Akta Agrosia* 13(1): 82-88.
- Suharjo, U.K.J. (2010b). Bringing down potato crops to lower elevation in Indonesi. *Proc. 2th Intl. Con. On Biosci. and Biotech.* Udayana University, Denpasar, Bali, pp: OA48-52, 23-24 September 2010, ISBN: 978-602-9042-11-5.
- Suharjo, U.K.J., Fahrurrozi, S. Sudjatmiko, and Popi Sabra. (2012). Memacu pembentukan dan pertumbuhan umbi kentang di dataran rendah Bengkulu dengan aplikasi anti-GA dan penyiraman air pada waktu yang berbeda. *Prosiding Seminar Nasional: Menuju Pertanian Bedaulat, Kerjasama antara Fakultas Pertanian UNIB, PERHEPI Komda Bengkulu, dan PFI Komda Bengkulu, Bengkulu*, pp: 42-51, 12 September 2012. ISBN: 9786029071078.



International Seminar on Plant Protection
Faculty of Agriculture, University of Bengkulu
Department of Plant Protection, Faculty of Agriculture, University of Bengkulu,
Indonesia

Volume 1, No. 1, June. 2025

Taiz, L and E. Zeiger. (2005). Plant Physiology 5th Ed. Sianuer Assoc. Massachusset.
USA.