Performance of the Third Generation of Vegetative Propagated Gamma Irradiation Induced Mutant (MV3) Potato Crops Exposed to Water Deficit at Medium Elevation

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ABSTRACT

Due to its complex ploidy levels, potato crop improvement by hybridization becomes very difficult. It involves endosperm balance number (EBN) that makes hybridization more complicated. Because of this, more researchers employ induced mutation, which is done by irradiating plant materials by gamma rays at designated levels, as an alternative method for potato crop improvement. The objective of this experiment was to study the performance of potato crops (MV3 generation) exposed to water deficit at medium elevation. Potato seeds (MV3) were grown in the greenhouse at 600 m above sea level and exposed to different level of water stress regimes. Some MV3 UNIB promising clones (KHSTM-7; KHSTM-8, and KHSTM-9) were found to be suitable for medium elevation having daily temperature of 28^{o}C. However, when exposed to drought stress induced by 10% of PEG8000, most of the clones showed significant yield loss (up to 86%).

Key words: crop improvement, mutant, gamma rays, water deficit, and medium elevation.

INTRODUCTION

It is well-known that potatoes are temperate crops sensitive to drought and heat stress (Bansal *et al.*, 1991; Reynold *et al*., 1989; Sarquis *et al*., 1996). However, no irrigation is available for potato in Indonesia. Growing potato at medium elevation without proper irrigation is quite challenging. Therefore, growers need to have a suitable production technology and/or suitable clones to ensure the yield (Ekanayake and de Jong, 1992; Stark and Love, 2003). Suitable clones for medium elevation may be obtained by irradiating potato clones with Gamma rays to produce mutant, which expected to be tolerant to water and heat stress. Suharjo *et al.* (2009) found that irradiation of 30 Gy gamma rays increased tuber number and tuber tolerance to water deficit at medium elevation (600 m above sea level). Further selection was done by planting promising clones (clones producing 28-32 tubers at medium elevation) at medium elevation. This experiment was carried out to evaluate the performance of UNIB promising clones at medium at medium elevation exposed to water deficit

MATERIALS AND METHODS

Evaluating the Performance Stability of UNIB Promising Clonnes against at Medium Elevation

The experiment, arranged in complete block design with 2 factors and 5 replications, was conducted at the screenhouse from May to August 2011 to evaluate the performance of potato crops grown at two levels of elevations (600 m and 1200 m above sea level). The potato crops evaluated were commercial cultivars (Atlantik and Granola), local cultivar (Red-skinned potato), and 12 promising clones developed by UNIB.

Whole seed tubers of G2 (approximately 50 g each) was planted in a polybag containing a mixture of top soil, sand, and manure (1:1:1, v/v). The polybags were put in the greenhouse, watered, fertilized, and treated accroding to the standard protocol for raising potato crops suggested by Stark and Love (2003). Key variables, including number of tubers, weight of tubers, and diameter of tubers were measured at the harvesting time. The data were analyzed by analysws of variance (ANOVA) followed by analyses of mean values according to Dunca's Multiple Range Test (DMRT) at 5%.

Evaluating the Performance Stability of UNIB Promising Clonnes against Drought Stress at Medium Elevation

The experiment, arranged in complete block design with 2 factors and 5 replications, was conducted at the screenhouse from July to October 2011 to evaluate the performance of potato crops grown at the medium elevation of Bengkulu (600 m above sea level) and exposed to two levels of water treatment induced chemically by PEG8000 (0 and 10%). The potato crops evaluated were commercial cultivars (Atlantik and Granola), local cultivar (Red-skinned potato), and 12 promising clones developed by UNIB. The planting method, variable measurement, and data analysis were done the same way as the experiment 1.

RESULTS AND DISCUSSION

Evaluating the Performance Stability of UNIB Promising Clonnes under Heat Stress at Medium Elevation

The results showed that the range of tuber number of the promising clones were higher than that of the commercial clones (Granola and Atlantic), both at the 600 m a.s.l. and high 1200 m a.s.l. (Table 1). However, only a few of the promising clones kept their ability to produce tubers at medium elevations, as shown by the significant reduction in growth and yield (Table 2).

'*Klon Harapan Seleksi Tebat Monok'* (KHSTM)s were promising clones obtained from the second generation of vegetative mutant (MV2) potato crops selected from previous program. When grown at medium elevation in Tebat Monok (600 m a.s.l.), these clones produced 32 tubers with the total fresh weight of 535 g.hill^{-1} (Suharjo *et al*., 2010). These clones (MV2) were generated from the MV1 of the previous crops producing 3,0–30,0 tubers with tuber yield range from 120,1-206,6 g.hill^{-1} (Suharjo *et al*., 2009).

Considering the yield of the previous crops (MV1 and MV3) and those of these crops (MV3), it is safe to assume that most of these clones had shown similar yield, ranging from 8,1-31,6 tubers (Table 1). In other words, these clones had shown its yield stability when grown at medium elevation.

At 600 m a.s.l. the highest number of tubers shown by KHSTM-4, KHSTM-7, KHSTM-9, KHSTM-11, and KHSTM-12 (Table 2). Moreover, compared to those grown at high elevation (1200 m a.s.l.), most of the promising clones grown at medium elevation (600 m a.s.l.) showed yield reduction of less than 20% (Table 2).

Table 1. Performance of UNIB promising potato clones at medium (600 m a.s.l.) and high elevation (1200 m a.s.l) after being irradiated with 30 Gy of Gamma rays, expressed in range of tuber number, tuber fresh weight, and tuber diameter

Potato Genotype	Tuber number		Tubers fresh weight (g)		Tuber Diameter (mm)	
	Medium Elevation (600 m)	High Elevation (1200 m)	Medium Elevation (600 m)	High Elevation (1200 m)	Medium Elevation (600 m)	High Elevation (1200 m)
Atlantik	8.2-10.8	6.8-10.1	190.4-230.1	350.1-451.3	11.1-26.6	10.1-49.6
Granola	6.5-12.9	9.8-16.1	123.9-260.9	245.1-545.9	15.5-46.5	16.8-56.3
Lokal	12.5-21.8	15.1-30.1	360.9-545.3	459.3-690.3	9.8-41.0	9.0-45.9
KHSTM-1	8.9-29.8	16.1-22.4	231.8-436.8	422.4-521.2	4.9-49.0	7.9-59.0
KHSTM-2	9.8-25.8	14.9-25.9	221.0-345.7	398.2-498.3	5.9-51.0	9.0-56.2
KHSTM-3	8.7-29.8	12.2-30.1	198.8-325.9	254.9-487.6	3.8-56.8	6.9-56.8
KHSTM-4	10.5-31.6	16.6-32.0	214.8-354.0	385.0-501.5	8.1-45.9	8.3-54.9
KHSTM-5	9.8-25.8	14.6-28.9	190-5-412.8	298.6-611.0	6.2-46.8	8.9-55.4
KHSTM-6	8.5-22.1	14.8-23.9	218-0-357.2	342.9-469.1	9.8-48.9	10.4-50.3
KHSTM-7	13.4-27.1	11.3-27.8	219.0-486.9	312.4-455.9	7.2-50.9	9.4-50.9
KHSTM-8	5.8-21.9	8.9-25.7	254.1-412.8	336.8-487.2	8.1-51.3	9.9-54.2
KHSTM-9	15.2-25.8	20.1-33.1	359.0-538.2	455.8-659.9	7.3-44.8	9.6-49.0
KHSTM-10	8.1-20.8	12.1-23.9	128.9-412.4	421.0-548.9	12.1-48.9	9.5-54.9
KHSTM-11	11.9-29.1	8.9-32.1	215.8-311.4	365.2-499.0	10.2-48.8	10.1-55.9
KHSTM-12	9.8-31.1	8.7-32.4	153.7-376.8	311.8-477.1	9.8-50.4	9.0-51.8

Table 2. Average tuber number, average tuber fresh weight, and their percentage of reduction when the promising potato crops grown at different of elevations above sea levels.

Potato Genotype	Average tuber number			Average tuber fresh weight (g)		
	At 600 m	At 1200 m	% Reduction	At 600 m	At 1200 m	% Reduction
Atlantik	9,5 a	8,45 a	-12,42 a	210,4 a	401,2 a	47,59 c
Granola	9,7 a	12,9 ab	25,09 c	192,4 a	395,5 ab	51,35 c
Lokal	17,1 ab	22,6 bc	*24,12 c*	452,1 c	574,8 c	21,35 ab
KHSTM-1	19,4 ab	19,3 b	-0,52 a	334,3 bc	471,8 b	29,14 b
KHSTM-2	17,8 ab	20,4 b	12,75 b	283,4 b	448,3 ab	36,78 bc
KHSTM-3	19,3 ab	21,1 b	8,77 b	262,4 ab	371,3 a	29,33 b
KHSTM-4	21,1 b	24,3 bc	13,37 b	284,9 b	443,3 ab	35,73 bc
KHSTM-5	17,8 ab	21,8 b	18,16 bc	301,6 bc	454,8 b	33,67 bc
KHSTM-6	15,3 ab	21,3 b	*28,17 d*	287,6 b	406,1 ab	29,16 b
KHSTM-7	20,3 b	19,5 b	-3,58 a	352,9 bc	384,2 a	8,12 a
KHSTM-8	13,9 a	17,3 b	19,94 bc	333,5 bc	412,2 ab	19,06 ab
KHSTM-9	20,5 b	26,6 c	*22,93 c*	448,6 c	557,9 c	19,58 ab
KHSTM-10	14,5 a	18,1 b	19,72 bc	270,5 ab	484,9 bc	44,19 c
KHSTM-11	20,5 b	20,5 b	0,00 a	263,6 ab	432,1 ab	38,99 bc
KHSTM-12	20,4 b	20,5 b	0,59 ab	265,3 ab	394,5 a	32,75 b

Note: the number followed by the same letter at the same column means not significantly different at 5% of DMRT

However, only three clones (KHSTM-7; KHSTM-8, and KHSTM-9) showed tuber fresh weight reduction of less than 20% (Table 2). For example, KHSTM-9 showed tuber fresh weight of 448,6 g.hill^{-1} at 600 m a.s.l and 557,9 g.hill^{-1} at 1200 m a.s.l. Considering the fact that the daily temperature at 1200 m a.s.l. was 20 ^{o}C and that of at 600 m a.s.l.was 28 ^{o}C while the yield reduction of KHSTM-9 was less than 20%, it is safe to assume that KHSTM-9 was the best candidate for medium elevation (Bansal *et al.*, 1991; Suharjo, 2004).

Evaluating the Performance Stability of UNIB Promising Clonnes against Drought Stress at Medium Elevation

The results showed that exposing potato crops to water stress (10% PEG 8000) significantly reduced tuber number, tuber fresh weight, and tuber diameter (Table 3 and Table 4). The reduction in tuber number number and tuber fresh weight range from 41% to 82%, except for the fresh weight of KHSK-5, about 25% (Table 4).

Table 3. Performance of UNIB promising potato clones at medium elevation exposed to water stress (10% PEG8000) after being irradiated with 30 Gy of Gamma rays.

Potato genotype	Range of tuber number		Range of tuber fresh weight (g)		Range of tuber diameter(mm)	
	0% PEG	10% PEG	0% PEG	10% PEG	0% PEG	10% PEG
Atlantik	8.2-10.8	3.5-6.7	190.4-230.1	30.5-120.5	10.1-49.6	9.9-32.0
Granola	6.5-12.9	2.8-6.5	123.9-260.9	40.2-154.0	16.8-56.3	7.2-23.1
Lokal	12.5-21.8	3.4-8.9	360.9-545.3	30.8-130.6	9.0-45.9	4.9-20.1
KHSR-1	8.9-29.8	2.5-9.6	231.8-436.8	40.8-120.8	7.9-59.0	4.8-32.0
KHSR-2	9.8-25.8	3.2-9.8	221.0-345.7	48.0-140.8	9.0-56.2	5.4-28.0
KHSR-3	8.7-29.8	2.1-9.4	198.8-325.9	28.8-120.8	6.9-56.8	3.2-22.9
KHSR-4	10.5-31.6	3.8-10.3	214.8-354.0	44.9-200.1	8.3-54.9	4.5-20.3
KHSR-5	9.8-25.8	2.4-10.8	190-5-412.8	34.0-320.0	8.9-55.4	6.0-19.0
KHSR-6	8.5-22.1	3.8-9.8	218-0-357.2	32.0-210.0	10.4-50.3	2.9-25.8
KHSK-1	13.4-27.1	5.8-12.9	219.0-486.9	60.8-190.5	9.4-50.9	3.8-32.0
KHSK-2	5.8-21.9	1.4-8.9	254.1-412.8	40.8-140.9	9.9-54.2	4.8-30.5
KHSK-3	15.2-25.8	3.9-10.1	359.0-538.2	45.9-120.8	9.6-49.0	8.8-30.1
KHSK-4	8.1-20.8	3.1-9.9	128.9-412.4	54.6-132.8	9.5-54.9	7.8-32.0
KHSK-5	11.9-29.1	3.4-10.1	215.8-311.4	43.0-143.9	10.1-55.9	8.1-28.0
KHSK-6	9.8-31.1	4.5-10.5	153.7-376.8	38.0-128.0	9.0-51.8	6.5-31.0

These indicated that all of these promising genotypes were not tolerant to water deficit, since tolerant genotypes should only reduce their growth or yield less than 20% when exposed to abiotic stress, compared to the control (Bandal et al., 199). However, it was still unclear what caused the significant reduction in yield, because no toelrant genotype was included in the selection. At least theree possibilities might be proposed to explain the phenomenon. First, the genotypes tested were simply sensitive to the water deficit. Second, the concentration of PEG8000 used to induced drought was too high (10% PEG8000). When selecting the tolerance of potato genotypes against drought stress, Suharjo (2004) used only 8% PEG8000 and found that the tolerant genotypes showed less than 20% of growth reduction while the sensitive ones >20%. It is recommended that researchers should employed 8% PEG8000, instead of 10%, when selecting potato cultivar for drought tolerance. *Finally*, the significant reduction in yield might be caused by compounding factor of drought stress and heat stress. In Suharjo (2004) and Bansal *et al*. (1991) potato genotypes were exposed only to drought stress, while in this experiment potato genotypes were exposed to drought stress at medium elevation, whose daily temperature was 28 ^{o}C.

Table 4. Average tuber number, average tuber fresh weight, and their percentage of reduction when the promising potato crops grown at different of water regimes at medium elevation.

Potato Genotypes	Tuber number			Tuber fresh weight (g)		
	0% PEG8000	10% PEG8000	% Reduction	0% PEG	10% PEG	% Reduction
Atlantik	9,5 a	5,1 a	46,32 a	210,25 a	75,52 a	64,09 b
Granola	9,7 a	4,7 a	52,06 ab	192,01 a	97,14 ab	49,43 b
Lokal	17,2 ab	6,2 a	64,14 b	453,12 c	80,72 a	82,19 c
KHSR-1	19,4 ab	6,1 a	68,73 b	334,31 b	80,82 a	75,83 c
KHSR-2	17,4 ab	6,5 a	62,54 b	283,35 ab	94,41 ab	66,68 bc
KHSR-3	19,3 ab	5,8 a	70,13 b	262,35 ab	74,81 a	71,49 c
KHSR-4	21,1 b	7,1 ab	66,51 b	269,42 ab	122,51 b	54,53 b
KHSR-5	17,8 ab	6,6 ab	62,92 b	301,65 b	177,23 c	41,32 b
KHSR-6	15,3 ab	6,8 ab	55,56 ab	287,62 ab	121,21 b	57,93 b
KHSK-1	20,3 b	9,4 b	53,83 ab	352,95 b	125,65 b	64,40 bc
KHSK-2	13,8 ab	5,2 a	62,82 b	333,45 b	90,85 ab	72,75 c
KHSK-3	20,5 b	7,1 b	65,85 b	448,64 c	83,35 a	81,42 c
KHSK-4	17,5 ab	6,5 ab	62,75 b	270,65 ab	93,71 ab	65,37 bc
KHSK-5	20,5 b	6,8 ab	67,07 b	123,63 a	93,45 ab	24,39 a
KHSK-6	20,5 b	7,5 b	63,33 b	265,25 ab	83,12 a	68,71 bc

Among the genotypes tested, KHSK-5 was the best candicated for further selection, provided that the selecting agent used was 8% PEG8000 as recommended by Suharjo (2004).

CONCLUSION

Some MV3 UNIB promising clones ((KHSTM-7; KHSTM-8, and KHSTM-9) were found to be suitable for medium elevation having daily temperature of 28 ^{o}C, while the others were not. The clones suitable for medium elevation showed less than 20% of reduction in yield. However, when exposed to drought stress induced by 10% of PEG8000, most of the clones showed significant yield loss (up to 86%).

We recommended to use 8% of PEG8000, instead of 10% PEG8000, when selecting potato genotypes againts drought stress.

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