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Quality Components of Potato Tubers as Affected by Plant Growth Regulators

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Abstract: *Potato plays important roles in Ethiopia's economy through ensuring food security as well as source of income for potato farming community. In addition to breaking tubers' dormancy and enhancing sprouting, plant growth regulators (PGRs) are known to affect tubers' quality components of potatoes which are usually governed by genotypes and some other abiotic factors. However, whether PGRs affect tubers' quality components of Ethiopia's potato varieties has not been known and documented in the past. Hence, the present study was conducted to evaluate the effect of pre-treatment of seed tubers with different plant growth regulators on some tubers' quality components of two common potato varieties in Ethiopia. The study evaluated the effect of three PGRs viz. Gibberrelic Acid (GA_3), Benzyladenine (BA) and Benzylamino purine (BAP) at two concentrations (0.1mM and 0.2mM) and distilled water-DW as untreated control on some tubers' quality components of variety Belete and Jalenie at Kulumsa Agricultural Research Center, Southeast Ethiopia in 2018. Forty sprouted tubers from each treatment combination (two varieties and three PGRs at two concentrations with untreated control-DW) were planted per plot ($9m^2$) in a factorial experiment using Randomized Complete Block Design (RCBD) and replicated three times. The required agronomic practices such as cultivation (weeding), ridging, fertilization, pesticide application, etc. were applied uniformly to all experimental units as needed. The results showed that both varieties were different in their responses to the PGRs used, while BA and BAP showed a significant effect on most of the tuber quality components compared to GA_3 at the lowest concentration (0.1mM) although no significant difference was obtained between BA and BAP. However, the two varieties Belete and Jalenie were found to be different in the tubers' qualities measured and between plant growth regulators. Belete was better than Jalenie in terms of tubers' specific gravity, dry matter and starch content and total soluble solids regardless of the effect of the PGRs. Hence, either BA or BAP or both could be used as pre-treatment plant growth regulators to improve the quality components of potato tubers of the two varieties.*

Key words: *Potato, tuber formation, plant growth regulators, tuber qualities*

1. INTRODUCTION

Potatoes are the fourth most important food crop in the world [1] which consists of adequate amount of protein, starch, carbohydrates, essential amino acids, vitamins and minerals which are important in human nutrition [2]. Potato plays important roles in Ethiopia's economy through ensuring food security as well as source of income for potato farming community [3, 4].

In addition to growth, tuber yield and yield components, quality of potato tubers and their chemical compositions are also affected by different factors including genotypes, climate, cultural practices, chemical treatments, and edaphic factors [5, 6]. Tuber's dry matter and starch content, tuber solids content, and specific gravity are the most common indicators of tuber's quality in potatoes. Besides the influence of environment and genotype related factors, plant growth regulators (PGRs) (phytohormones) play significant roles in affecting potato tuber qualities through regulating tuber formation, growth and development [7, 8, 9].

In previous works however, different authors confirmed the use of plant growth regulators (PGRs) to break potato tubers dormancy and enhancing sprouting to speed up production of seed potatoes through doubling/or tripling production cycles per season [10, 11, 12, 13]. However, in addition to breaking tuber's dormancy and enhancing sprouting, the use of pre-treatment of seed tubers with PGRs on tuber's

quality parameters was not studied and well documented in Ethiopia. The aim of the present study was therefore, to evaluate the effect of pre-treatment of potato seed tubers with different plant growth regulators on some tuber's quality parameters of two common potato varieties in Ethiopia.

2. MATERIALS AND METHOS

2.1 Description of the Study Area

The experiment was conducted at Kulumsa Agricultural Research Center (KARC) located at 8º00'-8º02'N latitude and 39º07'-39º10'E longitude in an elevation of 2210 m.a.s.l. in Arsi Administrative Zone of the Oromia Regional State, 167 km, Southeast of Addis Ababa in the year 2018. The site has Luvisol soil types with average annual total rainfall of 828 mm while the main season receives 535 mm of rainfall. The mean annual minimum and maximum temperatures are 9.12 and 22.2°C, respectively. The coldest month is December whereas March and May are the hottest months [14].

2.2 Experimental materials and pre-treatment with PGRs

Medium sized (35-45mm in diameter) freshly harvested tubers of two common potato varieties (Jalenie and Belete) were obtained from Holetta potato seed multiplication field, West Shoa, Ethiopia. The tubers were treated with three PGRs viz Gibberellic acid (GA_3), Benzylamino purine (BAP) and Benzyladenine (BA) at 0.1 and 0.2mM concentrations and with distilled water (DW) as untreated control with modifications [10]. The experimental tubers were labeled and stored in a diffused light store (DLS) until dormancy was broken and 80% of the tubers showed visible sprouting (~2mm).

2.3 Treatments, experimental design and data analysis

Sprouted tubers from each treatment combination (two varieties and three PGRs at two concentrations with untreated control-DW) were arranged as treatments in a factorial experiment using Randomized Complete Block Design (RCBD). Forty tubers from each treatment combination were planted per plot ($9m^2$) with spacing of 75cm (inter-row) x30cm (intra-row) and treatments were replicated three times. The required agronomic practices such as cultivation (weeding), ridging, fertilization, pesticide application, etc. were applied uniformly to all experimental units as needed. Fertilizers were applied at the rate of 242kg ha^{-1} NPS and 150kg ha^{-1} Urea, in which Urea was applied in split application, half dose at full emergence and the rest half after 45 days. Late blight disease on the experimental plots was managed with Ridomil Gold MZ and Mancozeb fungicides. Each experimental plot was harvested at maturity and data for the intended parameters including tubers' specific gravity, dry matter and starch content and total soluble solids were measured accordingly.

Specific gravity of tubers (gcm^{-3}) was determined by the weight in air/weight in water method. Five kilograms of marketable tubers were randomly taken from each plot and weighed under water. Specific gravity was calculated using the following formula [15].

$$Specific\ Gravity = \frac{Weight\ in\ air}{Weight\ in\ air - Weight\ in\ water}$$

Tuber dry matter content (%) was determined from five fresh tubers randomly selected from each plot. The tubers were sliced and open air dried until the loss of 90% moisture content and dried in an oven at 65ºC for 24 hours until a constant weight was obtained. The dry matter percent was estimated according to [16].

$$Dry\ matter\ (\%) = \frac{Weight\ of\ sample\ after\ drying\ (g)}{Initial\ weight\ of\ sample\ (g)}\ x\ 100$$

Tuber Starch content (g/100g) was calculated from the specific gravity: $Starch(g/100g) = 17.546 + 199.07x(Specific\ gravity - 1.0988)$ [17]; while ***total starch content (t ha^{-1})*** was estimated by multiplying the total tuber yield by the portion of starch measured (g/100g). Finally, ***total soluble solids (^{0}Brix)*** of the raw potato samples was determined using a method as described by [18] using hand refractometer. The Brix was measured in the juice obtained after washing, crushing and extracting juice of the tuber samples.

Data for the measured parameters were subjected to analysis of variance using Gen Stat, 13th Edition (VSN Ltd, Oxford UK) statistical software package. Least significant difference (LSD) test at 5% probabilities was used to separate means when the analysis of variance indicated the presence of significant differences among treatments.

Table 1. Effect of Plant Growth Regulators on tubers **Specific Gravity** (gcm^{-3}) of Two Potato Varieties.

Varieties	**Gibberellic acid (GA_3)**		
	0.0mM	**0.1mM**	**0.2mM**
Belete	1.073ab	1.073ab	1.064bc
Jalenie	1.048cd	1.041de	1.025e
	Benzylaminopurine (BAP)		
	0.0mM	**0.1mM**	**0.2mM**
Belete	1.073ab	1.087a	1.065bc
Jalenie	1.048cd	1.06bcd	1.065bc
	Benzyladenine (BA)		
	0.0mM	**0.1mM**	**0.2mM**
Belete	1.073ab	1.086a	1.087a
Jalenie	1.048cd	1.049cd	1.04de
LSD (5%)	0.02		
CV (%)	1.1		

Means followed by the same letter(s) within columns and rows are not significantly different at 5% level of probability.

Table 2. Effect of Plant Growth Regulators on tubers **Total Dry Matter (%)** of Two Potato Varieties.

Varieties	**Gibberellic acid (GA_3)**		
	0.0mM	**0.1mM**	**0.2mM**
Belete	18.63^{ab}	18.5^{ab}	16.59^{bc}
Jalenie	13.13^{cd}	11.76^{de}	8.26^{e}
	Benzylaminopurine (BAP)		
	0.0mM	**0.1mM**	**0.2mM**
Belete	18.63^{ab}	21.52^{a}	16.88^{bc}
Jalenie	13.13^{cd}	15.72^{bcd}	16.79^{bc}
	Benzyladenine (BA)		
	0.0mM	**0.1mM**	**0.2mM**
Belete	18.63^{ab}	21.25^{a}	21.52^{a}
Jalenie	13.13^{cd}	13.37^{cd}	11.41^{de}
LSD (5%)	4.32		
CV (%)	16		

Means followed by the same letter(s) within columns and rows are not significantly different at 5% level of probability.

Table 3. Effect of Plant Growth Regulators on tubers **Starch Content** (g/100g) of Two Potato Varieties.

Varieties	**Gibberellic acid (GA_3)**		
	0.0mM	**0.1mM**	**0.2mM**
Belete	12.48^{ab}	12.36^{ab}	10.58^{bc}
Jalenie	7.35^{cd}	6.07^{de}	2.79^{e}
	Benzyl aminopurine		
	0.0mM	**0.1mM**	**0.2mM**
Belete	12.48^{ab}	15.19^{a}	10.85^{bc}
Jalenie	7.35^{cd}	9.76^{bcd}	10.77^{bc}
	Benzyl adenine		
	0.0mM	**0.1mM**	**0.2mM**
Belete	12.48^{ab}	14.94^{a}	15.19^{a}
Jalenie	7.35^{cd}	7.57^{cd}	5.74^{de}
LSD (5%)	4.03		
CV (%)	23.8		

Means followed by the same letter(s) within columns and rows are not significantly different at 5% level of probability.

Table 4. Effect of Plant Growth Regulators on tubers **Total Starch Content** (t ha^{-1}) of two Potato Varieties.

Varieties	**Gibberellic acid (GA_3)**		
	0.0mM	**0.1mM**	**0.2mM**
Belete	180.3cde	220.4cd	194.5cd
Jalenie	90.8de	64.8de	22.7e
Benzylaminopurine			
	0.0mM	**0.1mM**	**0.2mM**
Belete	180.3cde	392.8ab	276.9bc
Jalenie	90.8de	152.6cde	173.9cde
Benzyladenine			
	0.0mM	**0.1mM**	**0.2mM**
Belete	180.3cde	446.3a	421ab
Jalenie	90.8de	88.4de	62.1de
LSD (5%)	168.9		
CV (%)	50.5		

Means followed by the same letter(s) within columns and rows are not significantly different at 5% level of probability.

Table 5. Effect of Plant Growth Regulators on tubers **Total Soluble Solid** (^{0}**Brix**) of Two Potato Varieties.

Varieties	**Gibberellic acid (GA_3)**		
	0.0mM	**0.1mM**	**0.2mM**
Belete	3.73^{ef}	3.93^{de}	4.27^{cd}
Jalenie	3.47^{f}	3.93^{de}	4.00^{de}
Benzyl aminopurine (BAP)			
	0.0mM	**0.1mM**	**0.2mM**
Belete	3.73^{ef}	4.33^{bcd}	4.73^{ab}
Jalenie	3.47^{f}	3.93^{de}	4.87^{a}
Benzyl adenine (BA)			
	0.0mM	**0.1mM**	**0.2mM**
Belete	3.73^{ef}	4.47^{abc}	4.67^{abc}
Jalenie	3.47^{f}	4.80^{a}	4.67^{abc}
LSD (5%)	0.44		
CV (%)	6.1		

Means followed by the same letter(s) within columns and rows are not significantly different at 5% level of probability.

3. RESULTS

Analysis of variance showed that tubers pre-treated with the PGRs resulted in a highly significant ($p<0.001$) effect on specific gravity of both potato varieties (Table1). BAP and BA caused increment in specific gravity of tubers by 50.32% and 50.30% respectively at low concentration (0.1mM) on Belete variety, which was higher when compared with what was obtained from tubers pre-treated with Gibberellic Acid and the untreated control (DW) and without any significant change on Jalenie variety. On the other hand, both varieties showed differences in specific gravities regardless of the effect of the PGRs used while Belete was better than Jalenie with and without the use of any of the three PGRs treatments.

Likewise, BAP and BA highly significantly ($p<0.001$) affected tubers' total dry matter of the two varieties (Table 2). Both Belete and Jalenie are different in specific gravities as mentioned above (Table 1), which led to affect tuber's dry matter content of the two varieties. Pre-treatment of tubers with BAP and BA increased tubers' dry matter content on both varieties while the highest values were recorded at 0.1mM.

However, on the contrary GA_3 did not significantly increase tubers' dry matter content when the concentration increased from the untreated control (0mM) to the highest concentration (0.2mM). Like

the specific gravity, Belete was superior over Jalenie in tuber's dry matter content regardless of the pre-treatment of PGRs.

Tubers pre-treated with the PGRs highly significantly ($p<0.001$) affected tuber's starch content of both varieties (Table 3). Increasing the concentration of BAP and BA increased starch content of tubers on both varieties while the highest starch value (15.19%) was recorded due to the pre-treatment of tubers with BAP at 0.1mM and BA at 0.2mM. However, regardless of the use of the PRGs, Belete was found to be higher in tuber's starch content than that of Jalenie.

Increased tuber's starch content (%) increased the total starch content per hectare which was highly significantly ($p<0.001$) affected by the PGRs used on both potato varieties (Table 4).

Increasing the concentration of the PGRs increased the total starch content of tubers (t ha^{-1}) while the highest value for each PGR was recorded at 0.1mM concentration on variety Belete then it declined when the concentration increased to 0.2mM.

BA with low concentration (0.1mM) recorded the highest (59.6%) total starch content increment over the untreated control on Belete followed by the increment due to pre-treatment of BAP (54.2%), and GA_3 (22%) on the same variety- Belete. The starch content increment obtained on variety Jalenie was 47.7% due to pre-treatment of tubers with BAP at the highest concentration (0.2mM). Over all, Belete was superior and almost double the amount of tuber's total starch content compared to what variety Jalenie had regardless of the pre-treatment of PGRs.

Like the other tuber's quality components, tuber's total soluble solid (TSS) content of both potato varieties was highly significantly ($p<0.001$) affected by the pre-treatment of the PGRs used (Table 5). Seed tubers which was treated with BA recorded the highest TSS value (4.8) at low concentration (0.1mM) which was exceeded from the untreated control by 58.04% on variety Jalenie.

Using the same plant hormone (BA) at the highest concentration (0.2mM), 55.6% TSS increment was obtained on variety Belete over the untreated control. Treatment of tubers with BAP also increased tuber's TSS of Belete and Jalenie variety by 55.91% and 58.39% respectively at the highest concentration (0.2mM) over the untreated control. Like the other tubers' quality components discussed above, Belete showed its superiority again on tuber's TSS concentration over Jalenie with and without the effect of PGRs.

4. Discussion

Plant growth regulators (PGRs) including GA_3, BAP and BA as pre-sprouting hormones affected most of the tuber's quality components studied in the present study such as specific gravity, dry matter and starch content and total soluble solids. More importantly BA and BAP showed significant effects on those components probably due to its role in the development and formation of tubers and its quality constituents. According to [19, 20] BAP and BA representing cytokinins play important roles in plant growth, development, yield and consequently affect quality formation in tubers produced [19, 20]. Although the mode of application and forms of plant growth hormones are different from the present study, spraying yeast solution (source of cytokinins similar effect as BAP and BA) significantly increased different tuber's quality parameters including tubers' dry matter percentage and total soluble solids [21]. Besides, yeast as a natural source of cytokinins-stimulates cell division and enlargement as well as the synthesis and enlargement of protein, nucleic acid and chlorophyll [22, 23, 24] which definitely affects the quality components. Likewise, [25] found that foliar application of yeast increased cytokinins content in a Solonaceae crop-Eggplant especially at the high level of yeast (10 g/l.), which invariably influenced dry matter, starch and total soluble solids. Increasing the yeast concentrations were gradually increased the productivity of potato plants and the tubers quality in terms of specific gravity, starch %, protein % and dry matter % [26]. Several previous works are in accordance with the results of the present study in which plant hormones such as BAP and BA which replace cytokinins affected potato tuber's quality components through regulating tuber formation, and affecting different chemical properties of potato tubers [8, 27].

5. Conclusion and Recommendation

Tuber quality components of both varieties considered under the present study were affected by the three PGRs used to treat seed tubers before planting. Pre-treatment of seed tubers with BA and BAP showed a significant effect on most tuber quality components compared to GA_3 mostly at the lowest

concentration (0.1mM) although no significant difference was obtained between BA and BAP. However, the two varieties _ Belete and Jalenie were found to be different in tubers' quality components studied and between plant growth regulators. Belete was better than Jalenie in terms of tubers' specific gravity, dry matter content, starch content, total starch content and total soluble solids. Besides, the varieties were different in their responses to the plant growth regulators used. Therefore, from the results obtained, BA or BAP or both could be used as a pre-treatment plant hormones for seed potato tubers of the two varieties to improve the quality of potato tubers produced.

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