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SOLUTION pH ALTERATION ON INDUCTION OF TUBER INITIATION IN HYDROPONICALLY GROWN POTATOES

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ABSTRACT

Induction of tuber initiation in potatoes (*Solanum tuberosum* L.) is very important to increase the effectiveness of hydroponic systems grown in quality seed tuber production. Among different methods to increase the tuber induction, intermittent alteration of pH in the nutrient solution was evaluated in a hydroponics system to examine its effect on tuberization and to select the most effective intermittent pH to be maintained in the nutrient solution. Four different intermittent pH alterations (3.0, 3.5, 4.0 and 4.5) were compared with constant pH (5.5) and the intermittent pH were given for 8h at 4 and 6 weeks after planting. Popular potato variety Granola was selected for the experiment and plant height, number of stolons per plant and number of tubers per plants were evaluated. Intermittent solution pH was not significant on plant height at the early growth stages of potato plants. However intermittent pH of 3.5 showed significantly higher plant height at harvesting (54 cm). Number of stolons was significantly responded variations in intermittent pH alterations and the pH maintained at 3.5 intermittently resulted the maximum numbers of stolons (58) and tubers (38.66), achieving 110% increment compared to control. Overall results proved that alteration of pH in the nutrient solution was positive on tuberization of hydroponically grown potatoes and 3.5 was the optimum intermittent pH level.

Keywords: Hydroponics, Induction tuberization, pH alteration, Potatoes

INTRODUCTION

Pre basic seed production of potatoes is one of the important processes to maintain the quality of potato seeds. Advanced technologies such as hydroponics and aeroponics have been introduced to the seed production system of the Department of Agriculture recently to maintain the quality standards and high productivity compared to conventional geoponic systems. In hydroponics, plants are cultivated by placing their roots in a nutrient solution. A system where roots are continuously or discontinuously exposed to an environment saturated with fine drops (a mist) of nutrient solution is defined as aeroponics. A geoponic system consists of solid growing media (soil, coir dust, rock wool, *etc*.) to sustain the plant's root system. Potato growing in solid media has high risk of being contaminate with various soil borne diseases than the other two systems.

Hydroponic system is proven to be highly effective on tuberization and seed quality is superior due to tubers grown without any contact with substrate or nutrient solution (Kularathne *et al*., 2007). However, according to Tibbitts and Cao (1994), tuberization was inhibited when roots and stolons were immersed in solution or subjected to continuous mist in aeroponic systems reducing the productivity of those systems. Tuberization of potatoes in such a system can be promoted by applying stress conditions in mist culture such as N deficiency and interruption of mist for 12 hours to induced rapid tuberization, as documented by Waylen *et al*. (1994). Krauss and Marschner (1982) identified N deficiency as promoting tuberization in solution culture (hydroponic).

Stress created by low pH in hydroponics has been used to induce potato tuberization (Waylen *et al*., 1994), and there is a possibility to use a similar phenomenon to promote pre-basic seed potato production in local conditions. Therefore, the present study was undertaken with the objectives of increasing pre-basic seed production by intermittent pH reduction and to find out the optimum intermittent pH level to maximize the number of tubers per plant grown in hydroponics.

MATERIALS AND METHODS

The experiment was conducted the Regional Agriculture Research and Development Center, Bandarawela, from 2013 to 2014. A simple laboratory experiment was conducted to identify pH and Electrical Conductivity (EC) changes with different concentrations of selected Albert’s solutions prepared in pipe-borne water. pH and EC values were measured at 0 - 5 g /L concentrations made in 0.5 g /L splits. The experimental units were located in a top-vented poly-tunnel where day and night temperatures were maintained at 27±8 °C and 18±4 °C, respectively. Tissue cultured rooted stem cuttings of variety Granola was used as a planting material. A commercially available Albert's mixture was used as the nutrient solution. Initially, in 2013, an observational study was conducted in a non-circulating solution culture system in plastic boxes; with dimensions of 54 x 35 x 31cm with 6 plant experimental units, following exposure to four levels of intermittent pH (3.0, 3.5, 4.0 and 4.5) for 8 hours at 4 and 6 weeks after planting (WAP), with constant pH (5.5) as the control.

It was repeated twice in 2014 as a replicated experiment in a closed circulating type hydroponics system following the method described by Kularathne *et al*. (2007). The treatment structure was similar to that of the observational study. Replicated study was conducted in Complete Randomize Design. Nutrient solution pH was maintained at 5.5 ± 0.2 in all treatments except for the exposure time for intermittent pH alteration. Solution pH was lowered by applying 0.1M H_2SO_4 and raised by applying 0.1M KOH. At the initial stage of crop growth, the solution EC was maintained at 1.0 mS cm^{-1} and it was gradually increased up to 2.0 mS cm^{-1} at the later stage of the crop. Other cultural practices were done according to the Department of Agriculture recommendations. Plant height, number of stolons and number of tubers per plant were measured at 3, 5, 8 and 12 weeks after planting (WAP). Using SAS version 9.1. average data were analyzed by ANOVA procedure and Duncan's multiple range test was used for mean separation.

RESULTS AND DISCUSSION

pH and EC of Albert's solution in different concentrations

The pH and EC changes of different concentrations' of Albert's solution are shown in Figure 1. The initial pH and EC of the pipe borne water were 6.99 and 0.01 mS cm^{-1}, respectively. With gradual increments of application of Albert's solution by 0.5 g/ L, pH showed a negative correlation (R^2 = 0.959) and EC showed a positive correlation (R^2 = 0.996) with increasing solution concentration. The simple linier regressions developed (Figure 1) can be used to calculate pH and EC values of the Albert's fertilizer-based nutrient solution without using pH or EC meters and can be applied to resource- poor farmers.

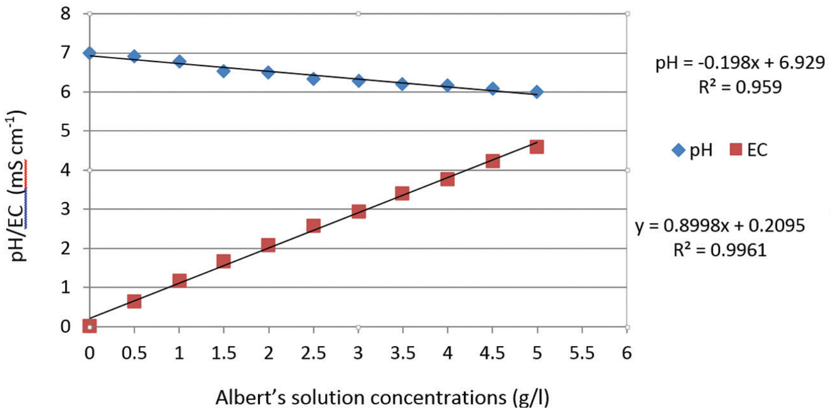

Figure 1. pH and EC changes of Albert's solution in different concentrations

In most hydroponic and aeroponic systems, the solution pH ranges between 5.5-6.5, and EC does not exceed 2 mS cm^{-1} (Nugaliyadde *et al*., 2005 and Mbiyu *et al*., 2012). In this study, the same pH and EC levels were maintained in the control and all experimental units, except the exposure time for intermittent pH.

Observational study - 2013

Observational study conducted in 2013 revealed no changes in plant height before imposing the pH treatments. However, one week after treatments, the intermittent pH 3.0 recorded the lowest plant heights, number of stolons and tubers compared to all other treatments. However, other pH alterations (3.5, 4.0, and 4.5) showed neutral or positive changes in the growth parameters. Height of the plants was not changed with respective treatments, but the number of stolons and tubers were increased with pH alterations compared to constant pH. The number of stolons and tubers per plant, were superior in intermittent pH 3.5 (Table 1).

Table 1 shows that the highest number of tubers per plant was recorded in intermittent pH 3.5, over the other treatments, and the lowest was recorded in intermittent pH 3.0. It is observed that intermittent pH has a positive effect on tuberization compared to constant pH treatment. However, observations proved that intermittent pH levels 3.5 adversely affected the growth of potato plants.

Table 1. Growth and yield of potato in different solution pH alterations in observational study- 2013.

Treatment (pH)	Avg. Plant height (cm) in 8 WAP	Avg. No. of stolons in 8 WAP	No. of tubers per plant at harvesting (12 WAP)
Control 5.5	32	42	13
Intermittent pH 3.0	26	32	09
Intermittent pH 3.5	31	59	29
Intermittent pH 4.0	32	52	23
Intermittent pH 4.5	32	52	21

Note: WAP: Weeks after planting

Replicated experiment - 2014

Plant height

Results revealed that the plant height was not significantly affected by different intermittent pH treatments until 12 WAP (Table 2). At early stages of growth, pH variations did not affect the plant height significantly. However, at 12 WAP, the effect on plant height was significant. The highest plant height was recorded in intermittent pH 3.5 and the lowest was recorded in intermittent pH 3.0 at 12 WAP. This observation was further confirmed as lower pH (3.0) cause adverse effects on the hydroponically grown potatoes.

Table 2. Variation in plant height of different pH alterations

Treatment (pH)	Plant height (cm)			
	3 WAP	5 WAP	8 WAP	12 WAP
Control 5.5	15.00^{a}	21.33^{a}	35.66^{a}	51.33^{abc}
Intermittent pH 3.0	15.00^{a}	20.00^{a}	34.33^{a}	48.00^{c}
Intermittent pH 3.5	14.50^{a}	21.50^{a}	35.66^{a}	$54.00a^{a}$
Intermittent pH 4.0	14.50^{a}	21.33^{a}	34.66^{a}	52.00^{ab}
Intermittent pH 4.5	14.66^{a}	22.00^{a}	35.33^{a}	49.66^{bc}
CV %	6.54	4.82	6.88	3.51
Mean	14.83	21.23	35.13	51.00

Means followed by the same letter in each column are not significantly different at p=0.05

Waylen *et al*. (1994) revealed through leaf mineral analysis at harvest, that the concentrations of several nutrients was varied at pH 3.5. That was a 40% increase in Mn and Fe and 10% decrease in N and P in plant tissues. It was justified as the toxicity of Mn and Fe levels and the deficiency of N and P levels adversely affected to the plant growth.

Number of stolons

Number of stolons was not significantly different before being exposed to treatments at 3 WAP. After the first application of intermittent pH treatment, there were significant differences at 5 WAP. Results showed significant increases of stolons with pH treatments compared to constant pH. Among pH variations, 3.5 gave the higest number of stolons throughout the experimental period (Table 3).

Table 3. Time course response of average number of stolons to intermittent pH

Treatment (pH)	Number of stolons plant^{-1}			
	3 WAP	5 WAP	8 WAP	12 WAP
Control 5.5	2.33^{a}	31.33^{c}	42.00^{b}	46.33^{d}
Intermittent pH 3.0	2.66^{a}	42.66^{b}	38.66^{b}	47.00^{dc}
Intermittent pH 3.5	2.66^{a}	51.33a	52.00^{a}	58.00^{a}
Intermittent pH 4.0	2.33^{a}	46.66^{b}	45.66^{ab}	54.33^{ab}
Intermittent pH 4.5	3.66^{a}	42.66^{b}	44.66^{ab}	51.33^{bc}
CV	12.33	5.36	9.23	4.54
Mean	2.73	42.93	44.60	51.4

Means followed by the same letter in each column are not significantly different at p=0.05

As observed, plants subjected to the pH reduction (3.5), produced shorter and thicker stolons compared to constant pH. Waylen *et al.* (1994) reported purple pigmentation at the end of the stolon when subjected to low intermittent pH (3.5), and these pigmented stolons have a high possibility of tuber formation. Since no colour changes were observed in this experiment, it may be associated with varieties. Nugaliyadde *et al*. (2005) have recorded 17.9 stolons per plant at 7 WAP in aeroponic system. In this hydroponic study, it was recorded higher than above values and mean number of stolons at 8 WAP in control treatment.

Tuber number

Significant induction of tuber formation was observed in potato plants in response to intermittent pH reduction, compared to control. Maximum number of tubers was recorded in pH 3.5 and it was around 110% increment over the control (Table 4). Pre-basic seed potato production in hydroponic culture is an expensive process due to the high initial cost (for infrastructure) and maintenance cost.

Table 4. Time course response of average number of tubers to intermittent pH

Treatment (pH)	Number of tubers/plant		
	5 WAP	**8 WAP**	**12 WAP**
Control 5.5	3.0[b]	12.66[c]	18.00[c]
Intermittent pH 3.0	4.0[ab]	12.00[c]	17.00[c]
Intermittent pH 3.5	5.0[a]	23.33[a]	38.66[a]
Intermittent pH 4.0	3.6[ab]	20.00[b]	26.33[b]
Intermittent pH 4.5	2.3[b]	18.66[b]	28.33[b]
CV	14.79	9.96	7.82
Mean	3.6	17.33	25.66

Means followed by the same letter in each column are not significantly different at p=0.05

This experiment revealed the possibility of doubling the system productivity only with pH alterations. However, solution pH lower than 3.5 had adversely affected the plant growth, reducing the number of tubers. Potato plant growth can be reduced in highly acidic conditions, as reported by Waylen *et al*. (1994), because of very low pH induced toxicity or deficiency of certain plant nutrients or the direct root injury by excess hydrogen. The treatment of intermittent pH 3.5 produced significantly higher numbers of tubers, probably due to changes in nutrient concentrations in leaf tissues, possibly affecting a particular physiological process to promote tuberization. Intermittent pH 4.0 treated plants exhibited no significant nutrient changes in plant tissues (Waylen *et al*., 1994). Kularathne *et al*. (2007) harvested 402 tubers per plant using a nutrient flow system, but our study resulted in a mean of 25.66, tubers per plant comparatively a low yield.

Tubers formed at intermittent pH 3.5 were identically medium-sized, compared to constant pH 5.5. It may be due to the initiation of tuberization at the same time of low pH stress and an important aspect to reduce the need of repeated harvesting, which requires more labor and increases the risk of contamination. Further, it will facilitate the harvesting of matured tubers at the end of the crop growth that can be stored without curing as a of this research.

There are some technologies available to impose stresses on potato plants under hydroponics systems to induce tuberization. Lowering N in nutrient solutions, changing the composition of nutrient solutions, circulating water without nutrients, and plants subjected to water stress are some of the strategies used to create stress conditions. However, imposing stresses with reduced pH is an easy, low-cost and efficient way to create stress on hydroponically grown potato plants to induce tuber initiation compared to other processes.

CONCLUSION

pH and EC values of Albert's solution showed a higher relationship with its concentration. Results proved that intermittent reduction of nutrient solution pH can significantly promote tuber initiation of hydroponically grown potatoes, with twice the productivity. Intermittent pH 3.5 for 8 hours at 4 and 6 WAP was the best pH alteration to obtain the maximum number of pre-basic seed potatoes in hydroponics systems.

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