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Determination of Nutrient Solutions for Potato (*Solanum tuberosum* L.) Seed Production under Aeroponics Production System

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Abstract: In soilless culture like aeroponics, nutrient optimization is the most critical factor to produce high quality and high yield of clean potato seed. Each crop has an optimum nutritional requirement. Even each potato cultivar may require a specific nutrient solution in an aeroponics unit. A nutrient optimization experiment was conducted at Holetta agricultural research center to study the effect of different nutrient solution levels on the physical quality and yield of potato mini-tubers. The treatments were four different nutrient solutions of greenhouse grade macro nutrients measured in (g) for the preparation of 500 liter volume of nutrient solution that is to be restocked when the nutrient tank becomes empty. The nutrient EC and pH were adjusted as per the requirements. A=(118 g $CaNO_3$, 252 g KNO_3, 68 g KH_2PO_4 and 100 g $MgSO_4$) ,B=(59 g $CaNO_3$, 126 g KNO_3, 68 g KH_2PO_4 and 100 g $MgSO_4$), C=(118 g $CaNO_3$, 252 g KNO_3, 68 g KH_2PO_4 and 100 g $MgSO_4$ until flowering and reduced by half after flowering), and D=(118 g $CaNO_3$, 252 g KNO_3, 136 g KH_2PO_4 and 100 g $MgSO_4$). All treatments included 2.2g of Fe EDTA and 6 g of Fetrilon combi. The potato variety, Belete, was used for the experiment. Acclimatized plantlets were planted randomly in each box of four treatments in CRD design with three replicates. The results showed that each treatment varied in nutrient consumption rate. Treatment A took the highest amount of nutrient (3.29 kg, 28%), treatments B and D consumed the same amount (3.1 kg, 27%), while treatment C consumed the smallest amount (2.02 kg). Root length was significantly affected by nutrient solutions. Nutrient solution C resulted the maximum root length (300.8 cm), while nutrient solution A produced minimum root length (135.5 cm). Plant height was not significantly affected by nutrient solutions. Small size tubers (<8 g) were not significantly affected by either tuber number or weight. Medium (8-12 g) and large size tubers (>12 g) were significantly affected by nutrient solutions both in number and weight. The maximum tuber numbers was obtained from treatment B. Therefore, the experiment indicated that treatment B represents the optimum nutrient concentration rate to use in an aeroponics mini-tuber production system under Holetta conditions.

Keywords: Aeroponics, nutrient concentration, mini-tuber, rapid multiplication, Ethiopia

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1 Introduction

Quality seed of an improved potato variety is a key to increase the productivity of a potato crop. The genetic potential and other traits of a potato variety are determined or manifested using healthy or improved seed. This is true because the usual method of propagating potato throughout the world is using the vegetative seed tuber.

Unavailability of healthy seed tubers in the required quantity and quality is probably the most important contributor to the low yield in Ethiopia (Berga and Gebremedhin 1994). Potato, like most vegetatively propagated crops, is disreputable of gradual yield decline when continually using the same seed tubers, which are kept from the same farm or obtained from unknown sources. Several seed production techniques are currently used worldwide to conquer such problems. These include: issue culture (micro propagation); hydroponics; aeroponics; etc. Among these, initial experimental studies have shown that aeroponics is one of the most effective techniques because of its various advantages over the other techniques (Ritter et al. 2001; Otazu 2008; Roosta 2012). Current efforts are underway to incorporate aeroponics into potato seed systems of some Sub Saharan African countries (Otazu 2010).

The Aeroponics system uses nutrient solution recirculation; hence, a limited amount of water is used. In soil-less culture, plants are raised without soil. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the World (Mamta and Shraddha 2013). It comparatively offers lower water and energy inputs per unit growing area (James et al. 1981; Ritter et al. 2001; Farran et al. 2006; Nabeel Mohammed 2016). Soon after its development, aeroponics took hold as a valuable research tool and offered researchers a non-invasive way to examine roots under development. In soilless culture like aeroponics, nutrient optimization is the most critical factor to produce high quality and high yield of clean potato seed. Each crop has an optimum nutritional requirement. Even each potato cultivar may require a specific nutrient solution in an aeroponics unit. Therefore, a nutrient optimization experiment was conducted at the Holetta agricultural research center to study the effect of different nutrient composition levels on the physical quality and yield of potato mini-tubers.

2 Materials and Methods

The experiment was carried out at the Holetta Agricultural Research Center in the potato research division at the aeroponics unit in the 2013/14 cropping season. The minimum and maximum relative humidity in unit one of the greenhouse, where treatments A and B were done, were 48.3% and 60% respectively, while the minimum and maximum recorded temperature were 18.6°C and 27.5°C respectively. The minimum and maximum relative humidity in unit two where C and D treatments where done were 38.7% and 59.7% respectively and the minimum and maximum recorded temperature were 18.5°C and 27.5°C respectively. The pH and EC of all four nutrient solution were adjusted to 6.8 and 1.5 ms/cm respectively.

The average minimum temperature of the nutrient solution in the tank were 10.6°C, 11.0°C, 11.2°C, and 11.1°C and the maximum temperatures were 15.7°C, 15.8°C, 16.0°C and 16.1°C for treatments A, B, C and D, respectively. *In-vitro* plantlets of the Belete variety, produced from the potato tissue culture laboratory, were acclimatized to the aeroponics greenhouse and planted in boxes having 4 m x 1 m x 1 m dimension, with a capacity for 80 plants at the spacing of 25 cm x 20 cm. There were four different nutrient compositions A=(118 g $CaNO_3$, 252g KNO_3, 68 g KH_2PO_4 and 100 g $MgSO_4$), B=(59 g $CaNO_3$, 126 g KNO_3, 68 g KH_2PO_4 and 100 g $MgSO_4$), C=(118 g $CaNO_3$, 252 g KNO_3, 68 g KH_2PO_4 and 100 g $MgSO_4$ until flowering and reduced by half after flowering) and D=(118 g $CaNO_3$, 252 g KNO_3, 136 g KH_2PO_4 and 100 g $MgSO_4$). All treatments included 2.2 g of Fe EDTA and 6 g of Fetrilon combi. Acclimatized plantlets were planted randomly in each box of four treatments in a Completely Randomized Design (CRD) with three replicates. Data was subjected to analysis of variance using proc GLM (general linear model) procedure of SAS 9.2 software (SAS Institute Inc. 2009). The means were compared with Least Significant Difference (LSD) at 5% probability level.

3 Results

Plant height and Root length: - Variation in nutrient solution is the fundamental factor that can bring change in plant height and root length (Table 1).

The length of root was measured by using a hand measuring meter through curtain windows of the box. Root length was significantly ($p<0.05$) affected by nutrient

Table 1: Effect of nutrient solution on plant height and root length

Treatments	Plant height (cm)	Root length (cm)
A	104.10ns	135.50b*
B	125.80ns	198.30b*
C	113.50ns	300.80 a*
D	148.30ns	174.40b*
CV%	13.49571	18.09864
LSD (5%)	40.06	101.63

** -means of the same factor followed by the same letter with in the column are not significantly different at 5% level of Probability, LSD-Least Significant Difference, CV% - Coefficient of Variance. Ns=no significant difference at 5% level of probability* solutions. Nutrient solution C provided the maximum root length (300.8cm) while nutrient solutions A produced the minimum root length (135.5cm). Plant height was not significantly affected by nutrient solution (Table 1).

Tuber size: - is the function of variety, nutrient and environment. It is noticeable that different tuber sizes are produced from different varieties when different nutrient solutions are supplied. The effect of different nutrient solution on tuber size, number and weight observed in this experiment was stated in table 2.

Tuber size: - harvested tubers were graded in three different sizes (small size (<8g), medium size (8-12g) and large (>12g)) and evaluated. Small size tubers were not significantly affected by different nutrient solutions in both number and weight. Medium size tubers were significantly different at different nutrient solutions in both number and weight. The maximum number of medium sized tubers were obtained from nutrient solution B (185) while A provided the minimum tuber number (41). Maximum medium sized tuber weight was obtained from nutrient solution B (1595.3g) while A provided the minimum tuber weight (352.6g) (Table 2).

Large size tubers were statistically different for different nutrient solutions in both number and weight. The maximum number of large tubers was registered from C (104) while the minimum was produced from A (19). The maximum weight of large tubers was registered from C (2090g), while the minimum was produced from A (350g).

Number of Tubers per plant:- nutrient solution had effect on tuber number harvested per plant. Treatment B produced the maximum number of tubers per plant and treatment A produced the minimum number of tubers per plant (Figure 1).

Total tuber number and weight(g):- The total tuber number and weight were affected by nutrient concentration levels. Treatment B produced the maximum total tuber number and weight while treatment A provided the minimum total tuber number and weight (Figure 2).

Table 2: Effect of nutrient solutions on tuber size, number and weight

Treatments	Small size (< 8g)		Medium size (8-12g)		Large (> 12g)	
	Number	Weight	Number	Weight	Number	Weight
A	162.00ns	688.5ns	41.00b*	352.6 b*	19.00 b*	350.0b*
B	313.00ns	1330.3ns	185.50a*	1595.3a*	103.00 a*	2060.0 a*
C	304.50ns	1294.1ns	184.50a*	1586.7a*	104.50a*	2090.0a*
D	336.50ns	1430.1ns	136.50ab*	1173.9ab*	29.00 b*	580.0 b*
CV%	31.34459	31.34459	34.81165	34.81165	31.23768	31.22918
LSD (5%)	242.80	1031.90	132.29	1137.7	55.399	1101.2

** -means of the same factor followed by the same letter with in the column are not significantly different at 5% level of Probability, LSD-Least Significant Difference, CV% - Coefficient of Variance. Ns=no significant difference at 5%level of probability*

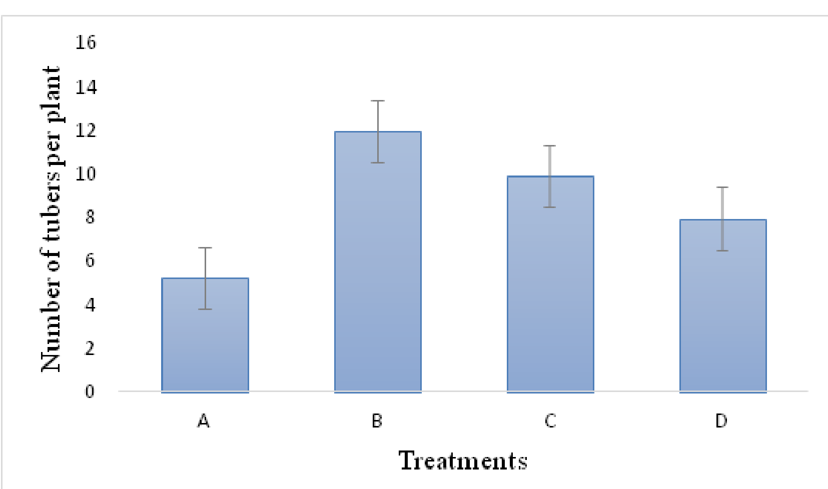

Figure 1: Effect of Nutrient solutions on tuber numbers per plant

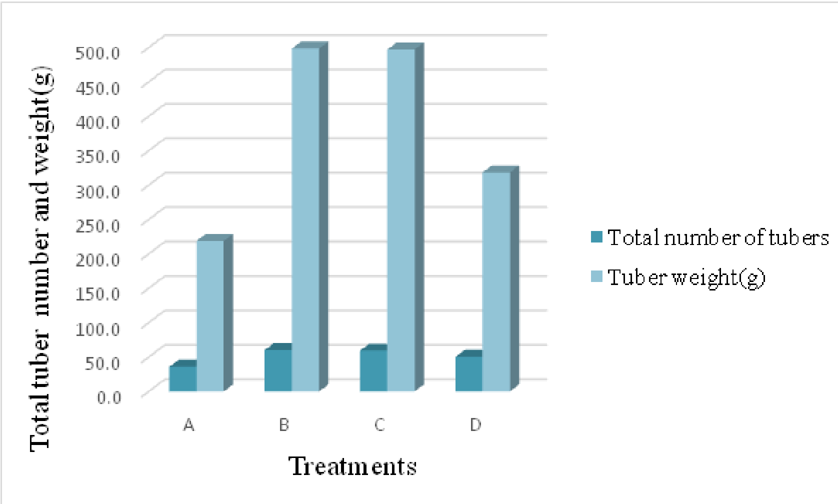

Figure 2: Effect of different nutrient solution levels on total number of tubers and weight

Plant survival rate: - plant survival rate among treatments showed variation. Treatment A had the maximum survival rate, 68 plants (85%) and the minimum was treatment B, 50 plants (63%). Treatment C and D had survival rates of 60 plant (75%) and 63 plants (78.8%) respectively.

Nutrient solution: - the amount of nutrient consumed by each treatment was different. Treatment A consumed 0.72 kg of calcium nitrate, 1.52 kg of potassium nitrate, 0.4 kg of potassium phosphate, 0.6 kg of magnesium sulfate, 0.012 kg of Iron EDTA, and 0.036 kg of Fetrilon combi. Treatment B used 0.52 kg of calcium nitrate, 1.1 kg of potassium nitrate, 0.56 kg of potassium phosphate, 0.84 kg of magnesium sulphate, 0.02 kg of Iron EDTA, and 0.052 kg of Fetrilon combi. Treatment C consumed 0.44 kg of calcium nitrate, 0.96 kg of potassium nitrate, 0.26 kg of potassium phosphate, 0.32 kg of magnesium sulphate, 0.012 kg of Iron EDTA, and 0.032 kg of Fetrilon combi, while Treatment D consumed 0.6 kg of calcium nitrate, 1.32 kg of potassium nitrate, 0.72 kg of potassium phosphate, 0.52 kg of magnesium sulphate, 0.012 kg of Iron EDTA, and 0.052 kg of Fetrilon combi.

4 Discussion

Potato is the third most important food crop in the world after rice and wheat in terms of human consumption (CIP 2013). Potato production in Sub-Saharan Africa (SSA) has more than doubled since 1994, with 70% of that growth concentrated in eastern Africa. FAO and CFC (2010) reported that despite these gains, potato yields of small-scale farmers in the region fall far short of their potential due mostly to a forceful combination of inadequate supplies of high-quality seed and smallholders' limited awareness of better seed management practices. Current efforts are underway in developing countries to access quality mini-tubers by performing rapid seed multiplication techniques including aeroponics.

High yields and product qualities of crops grown in soilless systems are highly depends on optimum nutrient supply. This implies the accurate management of all factors involved in crop nutrition: nutrient solution composition, water supply, nutrient solution temperature, dissolved oxygen concentration, electrical conductivity (EC) and pH of the nutrient solution. If any of these factors is non-optimal, plants may suffer from stress leading to a decline of yields and product qualities. EC and pH are useful indicators.PH is the negative log of hydrogen ion concentration of a substrate solution or a measure of acidity or basicity of a solution. The more hydrogen ions within the solution, the lower (more acidic) the PH value will be and vice versa (Bill et al. 2003). EC should not exceed 2.0 mS/cm. Similarly, pH should not exceed 7.3. Diluted phosphoric acid can be used to lower pH to a slightly acidic pH (6.5 - 6.8) (Otazu 2010). The EC and pH of the water used in the experiment were 1ms/cm and 7 respectively. These were adjusted to 1.5 mS/cm and 6.8 respectively for all treatments. The average minimum temperatures of the nutrient solution in the tank were 10.6°C, 11.0°C, 11.2°C, and 11.1°C and the maximum recorded temperatures were 15.7°C, 15.8°C, 16.0°C and 16.1°C for treatments A, B, C and D respectively. To specify the range of optimal conditions of a crop, a precise diagnosis of plant stress caused by an incorrect management of any of above mentioned factors is needed. An aeroponics system uses nutrient solution recirculation; hence, a limited amount of water is used. It comparatively offers lower water and energy inputs per unit growing area, as reported by Ritter et al. (2001).

In general, crop yield responds positively to increasing concentrations until an optimal level, after which further increases often lead to no further increases in yield (luxury consumption) as reported by Gorbe (2009). When concentrations are too high, yields may be even decreased (toxicity). The experiment, done in our aeroponics unit, similarly confirmed the above stated report. When the amount of nutrient concentration in nitrate fertilizers, like calcium nitrate and potassium nitrate (treatment A), increased, the mean total number of mini-tubers harvested were 357.5, but treatment B, which used less of these nitrate fertilizers, produced a greater yield 601.5 mini-tubers.

5 Conclusions

It is essential to have a good knowledge of plant mineral requirements to formulate optimum nutrient solutions. The ideal solution would provide the plant with the precise elements for producing the highest yield and/or quality and reduce the susceptibility to biotic and a-biotic stresses like nutrient deficiency related diseases of closis, greenhouse insect pests like red spider mites, aphid etc. In soilless culture like aeroponics, nutrient optimization is the most critical factor that requires timely modification based on existing situation of specific crop variety and agro-ecology. From the result, it can be concluded that different nutrient solutions significantly affected root length, and tuber size, both in number and weight. Therefore, treatment C (118g $CaNO_3$, 252g KNO_3, 68g KH_2PO_4, 100g $MgSO_4$, 2.2g of Fe EDTA and 6g of Fetrilon combi) until flowering and reducing by half of all the first four macronutrients, except Fe EDTA and Fetrilon combi after flowering is an appropriate nutrient solution rate for the Belete variety, under the greenhouse aeroponics cultivation system at Holetta.

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