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ORIGINAL ARTICLE

PRODUCTION OF POTATO UNDER SOILLESS CULTURE

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Abstract : This experiment was carried out using soilless system in the field of the College of Agriculture, University of Baghdad during the growing season of 2016 to investigate the influence of three growing media of sand, horse manure, and a mixture of both at equal amount designated as (M1, M2 and M3, respectively). In addition, three fertilization practices were applied including water, organic fertilizer named Drin and chemical fertilizer named pioneers and designated as (N1, N2 and N3, respectively) and their effect on growth and the productivity of three potato varieties Arizona, Pekaro, and *Rivera* (A,B, and C, respectively) were examined under polycarbonate house condition. The experiment was designed according to the RCBD in split-split plot with 27 treatments and three replications and means were compared following the least significant differences (LSD) test at 5% level of significance. The results can be summarized as follow: Rivera variety gave a significantly and the higher values of plant height, Chlorophyll content, Dry weight, Leaf area, Leaf area duration after 90 day, N%, K%, plant yield and tuber dry weight. Arizona variety gave the highest number of stems per plant after 90 days, P% and number of tuber per plant. The interaction treatments M1N1, AM3, AN2, M1N1 and AM3N1 gave a significantly highest number of tubers per plant. Treatment M1, treatment N1 and the interaction treatments CN2, BN3, M2N1 and BM3N3 significantly increased plant yield. The treatment M2 and N3 and the interaction treatments CM3, CN3, M3N3 and CM3N3 significantly increased tuber dry weight.

Key words : Soilless culture, Organic culture, Potato production, Fertilization.

1. Introduction

Agriculture depends on the usage of soil as a source of water and nutrient which deeply affected by the increasing in world population adding to drought and salinity that diminish the total green lands. These factors influence the productivity of land and reduce both quantities and qualities of agricultural commodities zone. Therefore, there is a need to find a new method to increase crop productivity without entirely depending on soil, which can be achieved by the use of growing media such as sand, gravel, rock, wool or other water-holding materials. These media may be mineral-based or organic-based and may be natural or industrial [Greer and Steve (2000)]. These media can hold water and manage fertilizer application to the plants [AL-Rashid and Jamal (2001)]. This technique can be established anywhere and it will reduce the quantity of water and fertilizer along with decreasing water and soil pollution and reduce soil-borne diseases [AL-Sadawi and AL-Sahaf (2003)]. Choosing the growing media depend upon the kind of material useful to be used as soilless culture such as sand, gravel, rock, sawdust, or organic material either from plants or animals. The organic matter influence the growth and yield of agricultural crops through their influence on chlorophyll content, fresh and dry weight of shoot and root systems, number of roots and flowers by supplying the necessary micro and macro elements and affecting hormonal and enzymatic actions [Magdoff and Ray (2005)]. The organic material used as growing media contains a number of mineral elements which gradually released through the plant life span in addition to their property of holding water and plays a potential substitute for soil. There are number of organic wastes rich in cheap nutrient elements which can be used as growing media in soilless culture system [Bunt (1998), Abad *et al*. (2001) and Ebrahimi *et al*. (2012)], where horse manure is an example of such organic waste media. Potatoes *Solanum tuberosum* L. is a nutrient-sucking crop due to their heavy vegetative growth and high yield potential

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through the growing seasons (90-120 day from transplanting to harvesting) [Al-Sahaf (1994)]. Many research projects were focused on optimizing potato fertilization practices but none of which incorporated different types of growing media with nutrient application. The aim of this research work was to study the influence of growing media and nutrient solution on growth and productivity of three potato varieties in soilless system.

2. Materials and Methods

A field experiment was implemented in polycarbonate house, Department of Horticulture and Landscape Gardening, College of Agriculture, University of Baghdad, where potato tubers (40-50g) were planted in plastic pots (16 L) and field practices were applied as needed. The experiment was designed according to the RCBD with three replications in split-split plot design where potato varieties represent the main plot, substrates in sub-plot, while nutrients in sub-sub-plot [Al-Rawi and Khalafulla (1980)]. This combination yielded 27 experimental units (3×3×3) in which each treatment replicated three times and means were compared according to the LSD at 5% level of significance.

1. **Varieties:** Arizona, Pekaro and rivera (A, B and C, respectively)
2. **Substrate:** Sand, Horse manure, 1/1 of sand and horse manure (M1, M2, and M3, respectively).
3. **Nutrient:** Water, Drin (organic N 6.3%, organic carbon 19% weight/ weight and amino acids 19% weight/ weight) at 1ml L^{-1}, and Pioneers (chemical fertilizer) (N,P,K/ 20-20-20) at the rate of 1.25g pot^{-1} (N1, N2 and N3)

Plants were sprayed until drip point in the early mornings with the aid of water surfactant.

Studied characters include:

1. Vegetative growth

a. Plant height

b. Stem number after 30, 60 and 90 days

c. Leaf area (dcm^2) by digimizer after 30, 60 and 90 days

d. Leaf Area Duration dm^2 days: To correlate dry matter yield with LAI [Power *et al.* (1967)] integrated the LAI with time and called Leaf Area Duration. LAD takes into account, both the duration and extent of photosynthetic tissue of the crop canopy. The LAD is expressed in days after 30, 60 and 90 days.

$$LAD = L \times time$$

$$LAD = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

L_1 = LAI at the first stage

L_2 = LAI at the second stage, $(t_2 - t_1)$ = Time interval in days [Power *et al.* (1967)].

e. Leaf chlorophyll content (mg 100g fresh wet^{-1}): chlorophyll was extracted from fresh leaf following the protocol of Abaas and Abaas (1992) with 80% aceton. The extract optical density was measured on 645 and 665 nm wave length and chlorophyll content mgL^{-1} was determined according to the below equation:

Total chlorophyll (mg L^{-1})= 20.2 × OD 645 nm+ 8.02×OD663

mg L^{-1} change to mg 100g fresh wet^{-1} according to relation

$$\text{mg 100g fresh wet}^{-1} = \frac{\text{mg L}^{-1}}{\text{Final extract volume (L)}} \times \frac{100}{\text{Sample weight (g)}}$$

f. Leaves nutrient content (N, P, K) : Leaves were collected and washed under tap water and then dried on (60-70^{0}C) until weight stabled, sieved, and digested by H_2SO_4 and $HCLO_4$, nutrient determinate as below:

1. Nitrogen N% : by Micro Kjeldahl.
2. Phosphorus p%: phosphorus determined by using Ammonium molybdate and ascorbic acid using UV - VIS Spectrophotometer 80 D model on 662 nm.
3. Potassium K%: determined by Flame photometer.

g. Tuber's dry matter % : pieces of collected tubers were weighted and dried in oven at 60-70^{0}C until weight stable. After that weight and dry matter % measured according to equation

$$\text{Tuber Dry matte (\%)} = \frac{\text{Tuber Dry weight}}{\text{Tuber Fresh weight}} \times 100$$

h. Plant dry weight (g $plant^{-1}$): determined by measuring plant fresh and dry weight and calculated according to the given equation

$$\text{Plant dry matter (g plant}^{-1}) = \frac{\text{Plant dry weight}}{\text{Plant Fresh weight}} \times 100$$

i. Tubers number plant^{-1}: calculated by dividing plants tubers by plants count.

j. Productivity (g plant^{-1}): estimated from dividing the yield of experimental unit by the number of plant.

3. Results and Discussion

Vegetative growth is the final outcome of the interaction between the environment and the genotype which denotes plants field behavior and predict the yield. As indicator of plant strength, plant height was taken. Table 1 shows a significant effect of plant genetic structure where, C variety showed an increase in plant height with an average of 64.32cm plnt^{-1}, while the 'A' variety gave the lowest height of 53.37 cm. Moreover, M3 and N2 gave an average height of 60.65 and 58.69 cm, respectively while the M2 and N3 plants gave the lowest plant height of 52.78 and 56.46 cm, respectively. As for the interaction, M2×C, N2×C and N2×M3 gave an average height of 67.90, 66.41 and 63.44 cm, respectively while the M2×B, N3×A and N2×M2 plants gave the lowest height of 44.33, 50.44 and 51.29 cm, respectively. The interaction effect of N3×M2×C gave an average height of 68.33cm while the N1×M2×A and N2×M2×B plants gave the lowest height of 41.67cm. A significant effect of C variety was observed in terms of chlorophyll content in leaves which gave 181.32 mg 100g fresh weight while the A variety plants gave the least leaves chlorophyll content of 161.21 mg 100g fresh weight. On the other hand, M3 and N3 gave an average chlorophyll content of 180.49 and 175.66 mg 100g fresh weight, respectively while the M1 and N1 plants gave the lowest value of 159.83 and 167.53 mg 100g fresh weight, respectively. The interaction effect of M3×C, N3×C and N3×M3 gave an average leaves chlorophyll content of 187.78, 185.25 and 182.57 mg 100g fresh weight, respectively while the M1×A, N1×A and N1×M1 plants gave the least leaves chlorophyll content of 147.28, 157.57 and 151.59 mg 100g fresh weight, respectively. The three way interaction (N3×M3×C) gave an average leaves chlorophyll content of 189.46 mg 100g fresh weight while the N1×M1×A plants gave the least leaves chlorophyll content of 142.54 mg 100g fresh.

A significant outcomes were obtained from C, M3, and N2 in terms of plant dry weight that yielded 60.54, 57.34 and 56.63 g plant^{-1}, respectively while the A variety, M1 substrate and N1 nutrient gave the lowest plant dry weight of 50.65, 54.15 and 53.94 g plant^{-1}, respectively. The interaction effect of M3×C, N2×C and N2×M3 gave an average plant dry weight of 61.70, 60.69 and 58.00 g plant^{-1}, respectively while the M2×A, N1×A and N1×M1 plants gave the lowest plant dry weight of 49.88, 48.10 and 51.46 g plant^{-1}, respectively. In addition, N2×M3×C gave an average plant dry weight of 63.14 g plant^{-1} while the N1×M1×B plants gave the lowest plant dry weight of 46.70g. Data in Table 2 shows no significant differences among the varieties, substrate and nutrient concerning plant stem number while M3×B, N1×B and N2×M3 was superior (4.22, 4.33 and 3.95) stem plant^{-1}, respectively when compared with (2.88, 2.77 and 3.14) stem plant-1 in M1*A, N1*A and N2*M2, respectively. It is observed that after 60 days, A and B varieties and M3 substrate increased total plant stem by 5.03, 5.03 and 4.99 stem plant^{-1}, respectively while the C varieties and M1 substrate gave 4.10 and 4.29 stem plant^{-1}. There was a significant superiority of M2×A, A×N2, N3×A, B×N1, N3×B and N2×M3 (5.88, 5.22, 5.22, 5.225.22 and 5.16 stem plant^{-1}) respectively as compared with (3.66, 3.52 and 4.00 stem plant^{-1}) in M1×A, N3×C and N3×M1, respectively. Our data showed that the N3×M2×B was significantly superior (6.33) stem plant^{-1} over 3.00 stem plant^{-1} in both N1×M1×A and N2×M1×B. It was noted that the A variety and M3 substrate gave a significant increase in plant stems after 90 days and scored 6.14 and 6.35 stem plant^{-1} when compared with C variety and M1 substrate that gave 4.87 and 4.75 stem.plant^{-1} while M2×A, M3×B, N2×A, N3×B and N1×M3 showed significant superiority of 7.44, 7.44, 6.44, 6.44 and 6.66 stem plant^{-1}, respectively as compared with 4.11, 4.42 and 4.44 stem plant^{-1} in M1×A, N3×C and N2×M1, respectively. The all way interaction treatment N3×M2×A increased plant stem (8.00 stem plant^{-1}) as compared with (3.33 stem plant^{-1}) in N1×M1×A treatment. Data in Table 2 showed that B variety, M3 substrate and N3 nutrient significantly increased leaf area after 30 days of planting at (19.51, 17.11 and 16.33 dcm^2 plant^{-1}) as compared with the least leaf area of (12.33, 12.07 and 13.40 dcm^2 plant^{-1}) in C Variety, M1 substrate and N1 nutrient, respectively while M3×B, N3×B and N3×M3 gave a significant superiority in leaf area of (23.33, 20.66 and 18.33 dcm^2 plant^{-1}) as compared with (8.66, 10.33 and 10.55 dcm^2 plant^{-1}) in M1×C, N1×C and N1×M1. Finally, the interaction treatment N3×M3×B increased plant leaf area (25.00 dcm^2 plant^{-1}) as compared with (7.00 dcm^2 plant^{-1}) in N1×M1×C treatment.

Table 1 : Effect of varieties, substrate and nutrient on some vegetative characters.

Treatments		Height of plant cm plant^{-1}	Chlorophyll content mg100^{-1}	Dry weight g plant^{-1}
varieties	A	53.37	161.21	50.65
	B	55.00	170.62	55.53
	C	64.32	181.32	60.54
L.S.D.		1.45	2.73	1.61
Media	M1	59.35	159.83	54.15
	M2	52.78	172.83	55.21
	M3	60.65	180.49	57.34
L.S.D.		2.53	3.54	1.00
Nutrients	N1	57.54	167.53	53.94
	N2	58.69	169.96	56.63
	N3	56.46	175.66	56.14
L.S.D.		1.84	3.37	1.37
varieties *Media	M1*A	54.78	147.28	50.85
	M2*A	46.11	160.97	49.88
	M3*A	59.22	175.38	51.22
	M1*B	61.33	160.25	50.86
	M2*B	44.33	173.29	56.60
	M3*B	59.33	178.31	59.12
	M1*C	61.95	171.95	60.75
	M2*C	67.90	184.24	59.17
	M3*C	63.11	187.78	61.70
L.S.D.		3.70	5.33	1.88
varieties *Nutrients	N1*A	56.33	157.57	48.10
	N2*A	53.33	160.00	53.84
	N3*A	50.44	166.04	50.00
	N1*B	55.33	167.88	53.28
	N2*B	56.33	168.30	55.37
	N3*B	53.33	175.67	57.93
	N1*C	60.94	177.13	60.44
	N2*C	66.41	181.58	60.69
	N3*C	65.62	185.25	60.48
L.S.D.		2.81	5.16	2.29
Media *Nutrients	N1*M1	60.56	151.59	51.46
	N2*M1	61.33	160.62	56.43
	N3*M1	56.17	167.27	54.56
	N1*M2	52.05	172.91	53.93
	N2*M2	51.29	168.46	55.47
L.S.D.	N3*M2	55.00	177.13	56.24

Table 1 continued...

After 60 days of planting, C, M3, and N3 treatments showed an increase in leaf area of 44.91, 39.87 and 38.12 dcm^2 plant^{-1}, respectively as compared with 32.69, 33.68, and 36.21 dcm^2 plant^{-1} in A, M1 and N1, respectively. The interaction treatments M3×C, N3×C, and N3×M3 gave 46.74, 45.47 and 42.84 dcm^2 plant^{-1}, respectively with a clear augmented effect as compared with 25.97, 30.41, 33.58, 33.58 dcm^2 plant^{-1} in M1×A, N1×A, N1×M1, N3×M1. Nevertheless, N1×M3×C treatment gave 46.73 dcm2 plant^{-1} as compared with 24.80 dcm^2 plant^{-1} in N3×M1×A treatment. As for 90 days after planting, C, M3 and N3 significantly increased leaf area of 70.65, 52.58 and 50.10 dcm^2 plant^{-1}, respectively when compared with 26.02, 43.29, and 43.75 dcm^2 plant^{-1} in A, M1 and N1, respectively. The interaction treatments M3×C, N3×C, and N3×M3 showed a significant increase in leaf area and gave 79.65, 73.63 and 55.48 dcm^2 plant^{-1}, respectively when compared with 19.00, 22.92 and 38.68 dcm^2 plant^{-1} in M2×A, N1×A and N1×M1 treatments, respectively while N3×M3×C treatment gave 82.55 dcm^2 plant^{-1} as compared with 16.65 dcm^2 plant^{-1} in N2×M2×A treatment. Regarding the leaf area duration after 30 days, it was exhibited that the B variety, M3 substrate, and N3 nutrient gave 0.414, 0.363 and 0.346 dm^2 days while the 0.261, 0.256 and 0.284 dm^2 days in C Variety, M1 substrate and N1 nutrient. However, the interaction treatments showed a significant effect when M3×B, N3×B, and N3×M3 gave 0.495, 0.438, and 0.389 dm^2 days, respectively. On the other hand, M1×C, N1×C and N1×M1 gave the least leaf area duration of 0.184, 0.219 and 0.224 dm^2 days. The three way interaction N3×M3×B significantly increased leaf area duration to 0.530 dm^2 days while the N1×M1×A treatment gave 0.191 dm^2 days. The B Variety, M3 substrate and N3 nutrient significantly affect leaf area duration after 60 days of planting and gave 0.996, 0.955 and 0.932 dm^2 days as compared with 0.828, 0.896 and 0.922 dm^2 days in A variety, M2 substrate and N1 nutrient, respectively. The

Table 1 continued...

	N1*M3	60.00	178.08	56.43
	N2*M3	63.44	180.81	58.00
	N3*M3	58.22	182.57	57.60
L.S.D.		3.51	5.75	2.14
verities *Media *Nutrients	N1*M1*A	63.00	142.54	48.79
	N2*M1*A	54.33	148.49	55.02
	N3*M1*A	47.00	150.81	48.73
	N1*M2*A	41.67	158.79	47.79
	N2*M2*A	44.33	155.58	54.01
	N3*M2*A	52.33	168.53	47.83
	N1*M3*A	64.33	171.39	47.73
	N2*M3*A	61.33	175.94	52.49
	N3*M3*A	52.00	178.79	53.43
	N1*M1*B	66.67	151.07	46.70
	N2*M1*B	63.00	157.85	51.47
	N3*M1*B	54.33	171.83	54.41
	N1*M2*B	47.00	174.97	54.37
	N2*M2*B	41.67	169.19	56.28
	N3*M2*B	44.33	175.73	59.14
	N1*M3*B	52.33	177.60	58.75
	N2*M3*B	64.33	177.88	58.36
	N3*M3*B	61.33	179.46	60.23
	N1*M1*C	52.00	161.17	58.89
	N2*M1*C	66.67	175.51	62.81
	N3*M1*C	67.18	179.17	60.55
	N1*M2*C	67.49	184.97	59.63
	N2*M2*C	67.88	180.62	56.12
	N3*M2*C	68.33	187.13	61.75
	N1*M3*C	63.33	185.26	62.81
	N2*M3*C	64.67	188.61	63.14
	N3*M3*C	61.33	189.46	59.14
L.S.D.		5.67	9.60	3.77

interactions treatments of M3×C, N1×B, and N3×M1 also gave a significant increase in leaf area duration by 1.151, 1.129 and 1.048 dm^2 days while 0.722, 0.727 and 0.824 dm^2 days were for M2×A, N1×A and N1×M1, respectively. The interaction treatment N2×M3×C gave 1.221 dm^2 days but 0.640 dm^2 days in N3×M3×B treatment. After 90 days of planting, C Varity, M2 substrate and N2 nutrient significantly increased leaf area duration and scored 1.039, 1.026, and 0.997 dm^2 days when compared with 0.970, 0.970, 0.933 and 0.988 dm^2 days in A, B, M1, and N1, respectively. The M2×A, N1×C and N1×M2 interactions gave 1.062, 1.107, and 1.139 dm^2 days as compared to 0.792, 0.886 and 0.886 dm^2 days in M1×A, N1×A, and N1×M3 while N3×M3×A gave 1.237 dm^2 days as compared with 0.736 dm^2 days in N1×M1×A treatment. The results in Table 3 showed that N% in the leaves in C variety, M3 substrate, and N3 nutrient had the highest means of 2.51, 2.33, and 2.26%, respectively whereas the lowest means of 1.93, 2.03 and 2.00% were at the 'A' variety, M1 substrate and N1 nutrient, respectively. The interaction between M3×C, N2×C, and N2×M3 significantly increased N% and gave 2.68, 2.56, and 2.41% while M2×B, N1×A and N1×M1 gave the least means of 1.86, 1.71 and %1.77, respectively. The highest value of nitrogen percentage was exhibited in N3×M3×C treatment which gave 2.74% while the least value of 1.48% was in N1×M1×A treatment. A significant phosphorous leaf percentage was recorded in A and N3 which yielded 0.62 and 0.64%), respectively while the least were 0.45 and 0.47% in C Varity and N2 nutrient. The M1×B, N3×A, and N3×M1 treatments increased phosphorus percentage to 0. 68, 0.87 and 0.70%, respectively as compared with the lowest means of 0.42, 0.43 and 0.46% in M1×C, N3×C, N2×M1 and N2×M2, respectively. Subsequently, N3×M3×A interaction treatment gave higher phosphorus percentage of 0.89% as compared with 0.26 in N1×M1×A treatment. The C Variety, M3 substrate, and N3 nutrient resulted higher K% of 3.56, 3.54 and 3.48%, respectively while the least percentages of potassium were 3.13, 3.17 and 3.25% which observed in A Varity, M1 substrate, and N1 nutrient, respectively. The M3×B, N3×C, and N3×M3 interaction treatments gave higher K% of (3.75, 3.64, and 3.61%) respectively as compared with 2.97, 2.87 and 2.90% in M1×A, N1×A and N1×M1, respectively. Finally, N3×M3×B interaction treatment showed higher K% of 3.86% as compared with 2.26% in N1×M1×A treatment.

The 'A' variety, M1 substrate and N1 nutrient showed significant superiority in plant tuber count of

Table 2 : Effect of varieties, substrate and nutrient on stem number, leaf area and leaf area duration.

Treatment		Stem No. after 30 day stem plant^{-1}	Stem No. after 60 day stem plant^{-1}	Stem No. after 90 day stem plant^{-1}	Leaf area after 30 day dcm^2 plant^{-1}	Leaf area after 60 day dcm^2 plant^{-1}	Leaf area after 90 day dcm^2 plant^{-1}	Leaf area duration after 30 day	Leaf area duration after 60 day	Leaf area duration after 90 day
Varieties	A	3.29	5.03	6.14	13.00	32.69	26.02	0.276	0.828	0.970
	B	3.85	5.03	6.07	19.51	34.19	43.67	0.414	0.996	0.970
	C	3.32	4.10	4.87	12.33	44.91	70.65	0.261	0.955	1.039
L.S.D.		0.64	0.28	0.22	0.41	1.25	0.987	0.0089	0.067	0.055
Substrate	M1	3.38	4.29	4.75	12.07	33.68	43.29	0.256	0.929	0.933
	M2	3.37	4.88	5.98	15.66	38.24	44.47	0.332	0.896	1.026
	M3	3.71	4.99	6.35	17.11	39.87	52.58	0.363	0.955	1.021
L.S.D.		0.52	0.29	0.39	0.32	0.98	1.882	0.0069	0.065	0.043
Nutrient	N1	3.39	4.75	5.63	13.40	36.21	43.75	0.284	0.922	0.988
	N2	3.47	4.76	5.72	15.11	37.46	46.50	0.320	0.926	0.997
	N3	3.59	4.65	5.73	16.33	38.12	50.10	0.346	0.932	0.994
L.S.D.		0.34	0.35	0.27	0.30	1.03	1.482	0.0065	0.077	0.050
Varieties * substrate	M1*A	2.88	3.66	4.11	11.33	25.97	33.49	0.240	0.952	0.792
	M2*A	3.44	5.88	7.44	15.00	35.00	19.00	0.318	0.722	1.062
	M3*A	3.55	5.55	6.88	12.66	37.10	25.57	0.268	0.812	1.057
	M1*B	3.33	4.11	4.44	16.22	32.14	34.77	0.344	1.083	1.027
	M2*B	4.00	5.44	6.33	19.00	34.67	43.71	0.403	1.003	0.915
	M3*B	4.22	5.55	7.44	23.33	35.76	52.52	0.495	0.902	0.969
	M1*C	3.93	5.11	5.70	8.66	42.93	61.62	0.184	0.752	0.979
	M2*C	2.66	3.31	4.18	13.00	45.05	70.70	0.276	0.963	1.101
	M3*C	3.36	3.88	4.72	15.33	46.74	79.65	0.325	1.151	1.037
L.S.D.		0.87	0.45	0.57	0.55	1.66	2.732	0.011	0.103	0.073
Nutrient * Varieties	N1*A	2.77	4.66	5.66	11.33	30.41	22.92	0.240	0.727	0.886
	N2*A	3.44	5.22	.44	13.33	33.75	25.13	0.283	0.817	1.000

Table 2 continued...

Table 2 continued...

	N3*A	3.66	5.22	6.33	14.33	33.90	30.01	0.304	0.941	1.024
	N1*B	4.33	5.22	6.11	18.55	33.57	40.72	0.394	1.129	0.971
	N2*B	3.22	4.66	5.66	19.33	34.01	43.64	0.410	0.986	0.972
	N3*B	4.00	5.22	6.44	20.66	35.00	46.65	0.438	0.873	0.967
	N1*C	3.07	4.36	5.11	10.33	44.63	67.61	0.219	0.911	1.107
	N2*C	3.76	4.41	5.07	12.66	44.62	70.72	0.268	0.976	1.018
	N3*C	3.12	3.52	4.42	14.00	45.47	73.63	0.297	0.980	0.992
L.S.D.		0.71	0.54	0.42	0.53	1.74	2.209	0.0114	0.120	0.082
Nutrient* substrate	N1*M1	3.33	4.77	5.11	10.55	33.58	38.68	0.224	0.824	0.933
	N2*M1	3.33	4.11	4.44	12.00	33.88	43.17	0.254	0.914	0.907
	N3*M1	3.49	4.00	4.70	13.66	33.58	48.03	0.290	1.048	0.958
	N1*M2	3.36	4.55	5.11	14.33	38.25	42.98	0.304	0.950	1.139
	N2*M2	3.14	5.02	6.29	15.66	38.51	43.65	0.332	0.865	1.017
	N3*M2	3.60	5.07	6.55	17.00	37.96	46.77	0.360	0.873	0.921
	N1*M3	3.48	4.92	6.66	15.33	36.78	49.58	0.325	0.993	0.892
	N2*M3	3.95	5.16	6.44	17.66	39.99	52.67	0.375	0.999	1.066
	N3*M3	3.70	4.90	5.94	18.33	42.84	55.48	0.389	0.873	1.104
L.S.D.		0.69	0.56	0.53	0.52	1.71	2.718	0.011	0.124	0.081
Nutrient* substrate* Varieties	N1*M1*A	1.66	3.00	3.33	9.00	25.67	25.60	0.191	0.735	0.736
	N2*M1*A	3.00	3.66	4.33	11.00	27.43	33.15	0.233	0.937	0.816
	N3*M1*A	4.00	4.33	4.66	14.00	24.80	41.72	0.297	1.183	0.824
	N1*M2*A	3.33	5.66	6.66	14.00	37.52	20.55	0.297	0.734	1.094
	N2*M2*A	3.33	6.33	7.66	15.00	35.84	16.65	0.318	0.672	1.079
	N3*M2*A	3.66	5.66	8.00	16.00	31.63	19.79	0.339	0.760	1.011
	N1*M3*A	3.33	5.33	7.00	11.00	28.05	22.59	0.233	0.713	0.829
	N2*M3*A	4.00	5.66	7.33	14.00	37.98	25.61	0.297	0.841	1.104
	N3*M3*A	3.33	5.66	6.33	13.00	45.28	28.50	0.276	0.881	1.237

Table 2 continued...

Table 2 continued...

	N1*M1*B	4.66	5.66	5.66	15.66	31.68	31.77	0.332	1.007	1.005
	N2*M1*B	2.00	3.00	3.33	16.00	32.39	34.76	0.339	1.078	1.027
	N3*M1*B	3.33	3.66	4.33	17.00	32.36	37.79	0.360	1.163	1.048
	N1*M2*B	4.33	4.33	4.66	18.00	33.47	40.82	0.382	1.249	1.093
	N2*M2*B	3.66	5.66	6.66	19.00	34.48	43.53	0.403	0.944	0.878
	N3*M2*B	4.00	6.33	7.66	20.00	36.08	46.76	0.424	0.817	0.774
	N1*M3*B	4.00	5.66	8.00	22.00	35.57	49.56	0.467	1.130	0.815
	N2*M3*B	4.00	5.33	7.00	23.00	35.16	52.61	0.488	0.935	1.013
	N3*M3*B	4.66	5.66	7.33	25.00	36.57	55.39	0.530	0.640	1.081
	N1*M1*C	3.66	5.66	6.33	7.00	43.40	58.68	0.148	0.731	1.058
	N2*M1*C	5.00	5.66	5.66	9.00	41.81	61.59	0.191	0.727	0.878
	N3*M1*C	3.14	4.00	5.10	10.00	43.57	64.59	0.212	0.799	1.001
	N1*M2*C	2.43	3.66	4.00	11.00	43.77	67.55	0.233	0.867	1.229
	N2*M2*C	2.44	3.06	4.54	13.00	45.21	70.77	0.276	0.979	1.094
	N3*M2*C	3.13	3.21	4.00	15.00	46.18	73.77	0.318	1.042	0.979
	N1*M3*C	3.13	3.76	5.00	13.00	46.73	76.60	0.276	1.135	1.033
	N2*M3*C	3.86	4.50	5.00	16.00	46.82	79.79	0.339	1.221	1.083
	N3*M3*C	3.10	3.37	4.18	17.00	46.67	82.55	0.360	1.098	0.994
L.S.D.		1.19	0.96	0.85	0.91	2.97	4.414	0.0193	0.212	0.081

6.48, 5.43 and 5.32 tuber plant^{-1}, respectively, compared with 3.89, 4.85, and 4.85 tuber plant^{-1} in C variety M2 substrate, and N3 nutrient. The M3×A, N2×A and N1×M1 interaction treatments gave higher plant tuber of 6.57, 6.63, and 5.87 tuber plant^{-1}, respectively as compared with 3.81, 3.73, and 4.70 tuber plant^{-1} in M2×C, N2×C and N3×M2, respectively. The N1×M3×A interaction treatment gave higher plant tuber of 6.90 tuber plant^{-1} when compared with 3.35 in N2×M1×C treatment. The C, M2 and N2 significantly increased plant yield which gave 544.7, 540.7, and 538.8 g plant^{-1} as compared with 500.0, 510.7 and 518.2 g plant^{-1} in A variety, M1 substrate and N3 nutrient, respectively. Moreover, M2×C, N3×B and N1×M2 interaction treatments gave higher yield at 569.1, 562.5 and 548.4 g plant^{-1} as compared with least means in M1×A, N3×A and N3×M1 which gave 486.1, 445.0 and 493.6 g plant^{-1}. The N3×M3×B treatment gave higher plant yield of 586.0 g plant^{-1} as compared with 422.1 g plant^{-1} in N3×M1×A treatment. The C variety, M3 substrate and N3 nutrient showed significant increase in tuber dry weight and recorded 18.16, 17.52 and 17.26 g plant^{-1}, respectively as compared with 15.40, 16.30 and 16.40 g plant^{-1} in A variety, M1 substrate, and N1 nutrient. The two way interaction treatments of M1×C, N3×C and N3×M3 gave higher tuber's dry weight and yielded 17.93, 18.36, and 17.92 g plant^{-1} as compared with 14.88, 14.59 and 15.18 g plant^{-1} in M1×A, N1×A and N1×M1 treatment, respectively while N3×M3×C treatment gave higher dry weight of potato tuber which reached 20.40 g plant^{-1} as compared with 12.22 g plant^{-1} in N1×M1×A treatment (Table 3). Potato varieties (Arizona, Pekaro and *rivera*) chosen in this study differed in their response to our proposed factors (substrate, nutrient) and clearly reflected on the number of stems, leaf area, and leaf area duration which can be related to the genetic makeup of these varieties. The N2 showed a significant effect on plant growth and can be attributed to its constitution of organic carbon and nitrogen in addition to a vast number of amino acids. This unique complex can promote auxin's production through the production of tryptophan where it considers a precursor for the naturally occurred auxin called indol acetic acid (IAA). The IAA plays an important role in increasing cell division and elongation and hence increasing plant height. Subsequently, nitrogen also participates in the synthesis of plant pigments including chlorophyll and therefore, increases photosynthesis efficiency which reflected on the number of leaves and the leaf area. Research parameters affected by the research factors appeared in plant tuber's number, plant yield, and tuber's dry weight which corresponded to their adaption to the surrounding environment. Research parameters differed in their response to the substrate especially M3 where a positive effect appears in the vegetative growth due to its constitution of equal ratio of horse manure and sand, thus, nutrients and aeration condition were adopted. Rough texture of our suggested substrate is important for water movement and root exploration. This clearly reflected on increasing plant height, dry weight, and leaf chlorophyll content hence increasing photosynthesis which accumulate carbohydrates and promote plant growth. As exhibited by Ali (2015), same substrate increased stem number, leaf area, and leaf area duration and was attributed to the substrate's effectiveness in terms of water and nutrient supply. The addition of organic matter to growing media will increase root aeration and it can also play a significant role in nutritional contribution to the soil mixture. In addition, heat will be generated due to the decomposition of organic substances and therefore, warming the soil which creates a preferential condition in the rhizosphere for increasing root biomass.

Potato varieties differed in nitrogen, phosphorus, and potassium accumulation in their leaves and that is attributed to their different genotypes. The N3 substrate increased leaves nitrogen and potassium percentage and therefore increased the vegetative parameters under investigation. Positive effect of M1 substrate (sand granules only) gave the highest tubers count due to the reduced mechanical resistance which help stolon formation and increased aeration. Nevertheless, M2 substrate gave higher vegetative growth which resulted in increased photosynthesis efficiency and lead to accumulate more carbohydrates in the tubers.

Highest plant height in N2 nutrient may be related to its contribution of organic nitrogen, organic carbon, and amino acids to the soil where root had spread and ready to absorb nutrient and increased vegetative growth parameters. Organic nutrient had the highest vegetative growth, shading percentage, and higher plant elongation because of the reduced auxin and gibberellin oxidation [Mumtaz *et al.* (1999)]. On the other hand, nitrogen promotes auxin production and protein synthesis which encourage cell division and elongation and elevate plant height [Sharake and Al-Khader (1985)]. Nitrogen indirectly increased photosynthesis which promotes energy for cell division and elongation [Taiz and Zeiger

Table 3 : Effect of varieties, substrate and nutrient in leaves nutrient percentage and yield characters.

Treatment		N%	P%	K%	Tuber number tuber plant^{-1}	Plant yield g plant^{-1}	Tuber dry weight g tuber^{-1}
varieties	A	1.93	0.62	3.13	6.48	500.0	15.40
	B	2.06	0.59	3.40	4.84	536.8	16.98
	C	2.51	0.45	3.56	3.89	544.7	18.16
L.S.D.		**0.13**	**0.12**	**0.21**	0.29	33.31	0.22
substrate	M1	2.03	0.55	3.17	5.43	510.7	16.30
	M2	2.13	0.55	3.38	4.85	540.7	16.73
	M3	2.33	0.55	3.54	4.92	530.1	17.52
L.S.D.		**0.05**	**0.05**	**0.09**	0.34	5.57	0.49
Nutrient	N1	2.00	0.54	3.25	5.32	524.5	16.40
	N2	2.24	0.47	3.36	5.02	538.8	16.89
	N3	2.26	0.64	3.48	4.86	518.2	17.26
L.S.D.		**0.08**	**0.09**	**0.14**	0.27	39.20	0.57
Varieties*substrate	M1*A	1.95	0.55	2.97	6.43	486.1	14.88
	M2*A	1.94	0.65	3.25	6.44	514.6	15.61
	M3*A	1.91	0.65	3.17	6.57	499.2	15.71
	M1*B	1.90	0.68	3.17	5.97	526.2	16.07
	M2*B	1.86	0.53	3.28	4.31	538.2	17.0
	M3*B	2.41	0.54	3.75	4.23	546.0	17.87
	M1*C	2.25	0.42	3.37	3.89	519.7	17.93
	M2*C	2.59	0.46	3.62	3.81	569.1	17.57
	M3*C	2.68	0.47	3.70	3.97	545.2	18.98
L.S.D.		**0.13**	**0.12**	**0.22**	0.52	55.19	0.71
Nutrient*Varieties	N1*A	1.71	0.48	2.87	6.50	517.8	14.59
	N2* A	2.12	0.49	3.15	6.63	537.2	15.35
	N3* A	1.96	0.87	3.36	6.31	445.0	16.26
	N1*B	1.87	0.67	3.45	5.33	510.8	16.76
	N2*B	2.03	0.46	3.31	4.70	537.1	17.05
	N3*B	2.27	0.63	3.45	4.48	562.5	17.14
	N1*C	2.41	0.46	3.45	4.13	544.8	17.85
	N2*C	2.56	0.46	3.61	3.73	542.0	18.27
	N3*C	2.55	0.43	3.64	3.81	547.2	18.36
L.S.D.		**0.16**	**0.16**	**0.26**	0.44	60.42	0.82
Nutrient*substrate	N1*M1	1.77	0.50	2.90	5.87	502.3	15.18
	N2*M1	2.09	0.46	3.22	5.29	536.1	15.81
	N3*M1	2.24	0.70	3.39	5.14	493.6	17.90
	N1*M2	2.04	0.60	3.35	4.99	548.4	16.92
	N2*M2	2.21	0.46	3.36	4.86	540.6	17.32

Table 3 continued...

Table 3 continued...

	N3*M2	2.14	0.57	3.45	4.70	532.9	15.95
	N1*M3	2.19	0.51	3.52	5.10	522.7	17.09
	N2*M3	2.41	0.50	3.49	4.91	539.6	17.55
	N3*M3	2.40	0.65	3.61	4.75	528.1	17.92
L.S.D.		**0.13**	**0.13**	**0.22**	0.50	44.02	0.92
Nutrient*Substrate *Varieties	N1*M1*A	1.48	0.26	2.26	6.23	482.4	12.22
	N2*M1*A	2.13	0.52	3.19	6.69	553.9	14.42
	N3*M1*A	2.23	0.87	3.45	6.38	422.1	18.00
	N1*M2*A	1.86	0.61	13.16	6.37	572.2	15.95
	N2*M2*A	2.14	0.49	3.16	6.59	510.6	15.65
	N3*M2*A	1.81	0.85	3.42	6.35	461.1	15.24
	N1*M3*A	1.81	0.59	3.19	6.90	498.9	15.61
	N2*M3*A	2.09	0.47	3.11	6.61	547.0	15.99
	N3*M3*A	1.83	0.89	3.20	6.19	451.7	15.55
	N1*M1*B	1.74	0.77	3.26	6.74	500.8	15.66
	N2*M1*B	1.86	0.43	3.09	5.82	536.7	15.47
	N3*M1*B	2.10	0.86	3.17	5.36	541.1	17.10
	N1*M2*B	1.69	0.74	3.31	4.91	504.3	16.45
	N2*M2*B	1.81	0.43	3.22	4.14	550.0	18.05
	N3*M2*B	2.09	0.42	3.33	3.88	560.3	16.50
	N1*M3*B	2.18	0.51	3.77	4.36	527.3	18.17
	N2*M3*B	2.41	0.53	3.63	4.13	524.7	17.63
	N3*M3*B	2.64	0.60	3.86	4.20	586.0	17.82
	N1*M1*C	2.10	0.47	3.17	4.65	523.7	17.67
	N2*M1*C	2.28	0.42	3.40	3.35	517.7	17.53
	N3*M1*C	2.38	0.39	3.54	3.68	517.7	18.59
	N1*M2*C	2.56	0.46	3.57	3.70	568.7	18.37
	N2*M2*C	2.69	0.46	3.70	3.85	561.3	18.25
	N3*M2*C	2.53	0.45	3.60	3.87	577.3	16.09
	N1*M3*C	2.58	0.45	3.61	4.04	542.0	17.51
	N2*M3*C	2.72	0.49	3.72	4.00	547.0	19.04
	N3*M3*C	2.74	0.46	3.77	3.88	546.7	20.40
L.S.D.		**0.24**	**0.25**	**0.41**	0.83	108.49	1.54

(2006)]. This was observed from the positive correlation between plant height and leaf area (.454**), highest chlorophyll content and leaves nitrogen percentage (correlation factor .592**) and leaf area and leaf number until 90 days (.340**). Our results showed that N1 significantly increased tuber's number because the tuber haven't osmatic pressure which increased cell division and increased rhizome number. The N2 increased plant's yield, which has organic nutrient and its effect on nutrient accumulation in vegetative system and sent it to tuber and increased its weight (Table 2) belongs to plant height and dry weight which appeared in correlation factor (0.362**) between plant dry weight and tuber yield, Tuber dry weight in N3 nutrient belongs to higher nutrient supplier ensures that from correlation factor (Table 4) between leaves N and K % and tuber dry weight (0.612**, 0.573**), respectively.

4. Conclusion and Recommendations

Table 4 : Correlation among vegetative characters of potato varieties.

	N	P	K	Cloro.	Dry wt./ plant	l.A 90	l.D 30	l D 60	l.D 90
N	1	-.195	.604**	.592**	.712**	.769**	.210	.146	.193
p		1	.239*	-.040	-.375-**	-.291-**	.230*	.178	.220*
K			1	.609**	.445**	.557**	.240*	.190	.175
Cloro.				1	.611**	.653**	.216	.174	.340**
Dry weight/plant					1	.757**	.096	.093	.095
l.A 90						1	.235*	.344**	.120
l.D 30							1	.571**	.643**
l D 60								1	.125
l.D 90									1

*, ** Correlation is significant at levels 0.05 and 0.01 respectively.

We can conclude that potato production in soilless system using organic fertilizers may lead to decrease in the chemical fertilizers to improve the quantity and quality just if we select the suitable variety and that depend on the intended market fresh, process or both. So, we recommend to use a mixture of growing media and horse manure with suitable doses of chemical fertilizer for getting the high yield and a good quality of tubers.

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References

Abad, M., P. Noguera and S. Bures (2001). National inventory of organic wastes for use as growing media for ornamental potted plant production. *Bio. Res. Technol.*, **77**, 197-200.

Ali, N. Sh. (2015). *Introduction to soil science*. Ministry of higher education and scientific research. University of Baghdad. College of Agriculture.

AL-Rashed, M.S. and M.A. Jamal (2001). ICARDA-APRP .Annual Report 2000/2001.

Al-Rawi, K.M. and A.A. Khalafulla (1980). *Design and Analysis of agricultural experiments*. Mosul, Iraq: University of Mosul, Ministry of higher education and scientific research, Mosul, Iraq.

Al-Sadawi, I.S. and F.H. Al-Sahaf (2003). Soilless culture for horticultural crop production. *The Iraqi J. Agric. Sci.*, **34(2)**, 67-82.

Al-Sahaf, F.H. (1994). Effect of number of spray with nutrient solution (Al-Nahrain) on growth and production of potato cv. Estima. *The Iraqi J. Agric. Sci.*, **25(1)**, 92-100.

Bunt, A. (1998). *Media and mixes for container grown plants*. Unwin Hyman, London ,pp 309

Ebrahimi, R., E. Fatemeh and A. Mostafa (2012). Effect of different substrates on herbaceous pigments and Chlorophyll amount of Strawberry in hydroponic cultivation system. *American-Eurasian J. Agric. and Environ. Sci.*, **12(2)**, 154-158.

Greer, Lane and Steve Diver (2000). ATTRA // Organic greenhouse vegetable production. 19pp.

Magdoff, F. and Ray R. Weil (2005). *Soil organic matter in sustainable agriculture*. CRC Press. London. p. 365.

Mumtaz, A.M., M.A. Pervez, FHGL M. Tahir and A. UL. Haq (1999). Effect of L-yield of potato cv, Pars-70.

Power, J.F, W.O. Willis, D.L. Grunes and G.A. Reichman (1967). Effect of soil temperature, phosphorus and plant age on growth analysis of barley. *Agron. J.*, **59**, 231-234.

Sharake, M. M. and A. Al-Khader (1985). *Plant physiology*. Baghdad University, Iraq. Pp 300.

Taiz, L. and E. Zeiger (2006). *Plant physiology*. 4th ed. Sinauer Associates. Inc. Publisher Sunderland, Massachus – AHS. U.S.A.