Growth and Yield of Potato *Solanum Tuberosum* L. as Influenced by Soaking in GA3 and Potassium Fertilizer Rates

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ABSTRACT

Gibberellic acid is a naturally occurring plant growth regulator which may cause a variety of effects, including the stimulation of seed germination by breaking seed dormancy. Gibberellins influence the dormancy of seeds, shoots, and other plant parts. Potato requires of balanced plant, mineral nutrients for growth and development without which yield and qualities of tubers are reduced. Potassium fertilizers are overlooked assuming that the soil is developed from K rich parent material and contains a sufficient amount of K to support crop growth. To achieve this aim, two field experiments were conducted during 2014 and 2015 seasons. Results revealed that increasing concentration of GA3 rates from 0 ppm GA3 to 30 ppm GA3 markedly increased plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch %. It could be stated that increasing of GA3 rates from 0 ppm GA3 to 30 ppm GA3 significantly increased plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % by 8.82, 9.35, 4.5, 4.58, 34.7, 12.23, 12.48, 11.96, 25.15, 13.69 and 19.04 %, respectively as an average of both seasons. The results indicated that increasing potassium fertilizer rates from 0 kgK2O/ha to 172.5 kgK2O/ha markedly increased plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch %. It could be noticed that increasing potassium fertilizer rates from 0 kgK2O/ha to 172.5 kgK2O/ha significantly increased plant height, chlorophyll content, foliage dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % by 3.6, 10.83, 9.02, 16.18, 6.69, 6.62, 11.47,7.11, 7.1 and 4.66 %, respectively as an average of both seasons. It could be concluded that soaking seed tuber in 30 ppm GA3 and adding 172.5 kgK2O/ha maximized tuber yield and its quality.

Keywords: *Gibberellic acid, Potassium fertilizer rates, Tuber quality.*

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1. INTRODUCTION

Potato *Solanum tuberosum* L. is one of the more often grown crops. In Egypt, potato is one of the most important foods not only to its local consumption, but also to increase net income through its exportation. To increase yield, it could be achieved by GA3 soaking and potassium fertilization rates. Their tubers are a good source of carbohydrates, proteins, vitamins, and minerals in human nutrition [1]. Plant growth regulators (PGR) have considerable effects on tuber fertility and it is highly related to hormonal balance. Foliar application of GA3 (5 and 10 ppm) increased the length of stems and stolons, and decreased the tuber fertility, but causes elongation of the stolons [2, 3]. Tawfik [4] reported that 120 kg K/feddan showed 25-30 % increase in fresh weight of tubers and lowered foliage fresh weight of cv. Spunta in sandy soil and drp-irrigation. In addition, the aforementioned dose gave 10-20% more tuber yield and large tubers than those receiving 60 kg k/ feddan. Karam, et al. [5] observed that K treatments (0, 96, 192, and 288 kg K/ha) significantly increased four potato varieties yield, but contrast responses were reported in dry matter % due to K applications on the different cultivars. Gibberellins play a very important role in regulates of growth and development in higher plants. Gibberellins at suitable concentration for minutes before planting was very effective to chlorophyll and increase vegetative growth parameters, improved tubers quality, tubers yield and its components are compared to the control. Application of gibberellic acid at low concentrations (5 and 10 mg/lit) was able to increase general performance and productivity of seed tubers of potatoes, seed tuber production was increased by application of using gibberellic acid in all cultivars, Also, results showed that after one week from application of GA3, starch content decreased and total content of sugar increased in potato tuber, furthermore, we indicated that sugar content is one of the important parameters determining the sprouting of seed potatoes. Soil potassium reserve in the soil is, generally, large, but most of it is incorporated in the crystal lattice structure of minerals thus becoming unavailable to plants. Additional K-containing sources are necessary to supply to provide optimal plant growth performance and yield [6]. Therefore, this investigation was aimed to investigate the effect of soaking in GA3 and potassium fertilization rates on growth, yield and tuber quality of potato.

2. MARERIALS AND METHODS

Two field experiments were performed in the extension field in Awish EL-Hagar village, Dakahlia region, Egypt during 2013/2014 and 2014/2015 seasons on a potato plant CV. Spunta. This study included four concentrations of GA3 seed tuber soaking i.e. 0, 10, 20 and 30 ppm GA3. Four potassium fertilizer rates i. e. 0, 57.5, 115, 172.5 kg K2O/ha were used.

Experiments with four replicates was arranged in a randomized complete block using split plot design. Four soaking in GA3 treatments were arranged randomly in the main plot. The four of potassium fertilizer rates were assigned in in the sub-plot. Tuber seeds were sown at 25 cm apart on January 2th and 4th during the 1st and 2nd seasons, respectively. The experimental unit area was 12.6 m^2. It contains three rows with 6 m length each and 70 cm distance between the two rows. One row was used to measure the dry weight of different organs/plant and plant chemical analysis and the other two rows were used for yield determinations. Potassium sulphate (48% K_2O) was used as a source of potassium. The amount of potassium fertilizer was divided into two equal portions applied in preparing the soil for planting, then 45 days after sowing.

Soil randomized samples were obtained from the experimental soil at the depth of 0 - 30 cm before planting to determine the physical and chemical contents according to standard method. Soil is loamy clay with pH 6.8 and 8, organic matter was 6 and 6.2%, available nitrogen was 24.5 and 24.8 ppm, available potassium was 213 and 228 ppm and available phosphorus was 9.8 and 8.9 ppm in the first and second season, respectively.

The soil was well prepared through two ploughing, leveling, compacting, ridging and division and then divided into the experimental units. Calcium superphosphate (15.5 % P2O5) was applied during soil preparation at the recommended level of 240 kg/ha. Nitrogen fertilizer was added in the form of ammonium nitrate (33.3 % N) at the recommended level of 400 kg/ha. The common agricultural practices for growing potato plants according to the recommendations of the Ministry of Agriculture were followed, except the factors under study.

The crude protein percentage was calculated by multiplying the total nitrogen percent by 6.25 as described by Bolton [7].

2.1. Studied Traits

Vegetative growth as plant height and plant shoot fresh and dry weight were determined after 70 days of planting.

1-Plant height.

2-Chlorophyll content: Leaf chlorophyll content was assessed by SPAD-502 (Minolta Co. Ltd., Osaka, Japan).

3-Foliage fresh weight g/plant.

4- Foliage dry weight g/plant: Total foliage dry matter was determined by oven drying at 70°C to constant mass.

At harvest, after 105 days from planting plants that produced from the three inner ridges from each -plot were harvested, and data were recorded for the following traits:

1- Number of tubers/ plant.

2- Average of tuber weight (g/plant).

3- Total tuber yield (ton/ha).

Quality parameters analyzed included TSS%, Crude protein %., Tuber dry matter % and starch%.

1-TSS%: Total soluble solids (TSS%) in tubers were determined.

2- Crude protein %: Crude protein percentage was determined by Kjeldal's method [8].

3- Tuber dry matter %: Dry matter was determined by drying small pieces of tubers at 80°C for 72 hours in an oven where the tuber dry weight% = (tuber dry weight at 80 °C /tuber fresh weight) *100,

4- Starch %: The amount of starch was determined by using a polarimetric method as described by Liutskanov, et al. [9].

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split-plot design to each experiment (row spacing), then combined analysis was done between row spacing trails as published by Gomez and Gomez [10] by using "MSTAT-C" computer software package. The least significant difference (LSD) method was used to test the differences between treatment means at the 5 % level of probability as described by Snedecor and Cochran [11].

3. RESULTS AND DISCUSSION

A. GA3 Concentration Effects

The results presented in Tables (1 and 2) clearly indicated soaking in GA3 concentrations significantly affected plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2014 and 2015 seasons. Results revealed that increasing concentration of GA3 rates from 0 ppm GA3 to 30 ppm GA3 markedly increased plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2014 and 2015 seasons. The corresponding data were 58.59, 31.01, 258.08, 88.71, 5.43, 491.1, 28.346, 5.35, 6.57, 18.39 and 15.15, respectively in the first season, and 58.92, 32.07, 258.15, 38.72, 5.45, 489.83, 28.341, 5.35, 6.62, 18.5 and 15.31, respectively in the second season. However, the lowest values of plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2014 and 2015 seasons were recorded from without GA3 soaking. It could be stated that increasing of GA3 rates from 0 ppm GA3 to 30 ppm GA3 significantly increased plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2014 and 2015 seasons by 8.82, 9.35, 4.5, 4.58, 34.7, 12.23, 12.48, 11.96, 25.15, 13.69 and 19.04 %, respectively as an average of both seasons. The pre-soaking application of gibberellic acid at low concentrations (5 and 10 mg/lit) is able to increase the general performance of seed tubers [12]. This achievement is very valuable because of two reasons; at first, in seed production programs, any increment of percentage of seed tubers is very important and second, it creates favorable conditions in vogue of tubers in industries by reduction of big tubers and making tubers of equal size. Application of gibberellic acid increases the productivity of tubers of a potato (Solanum tuberosum L.). The tubers treated with GA3 sprouted earlier, while non application of GA3 sprouted very late and slow. Further, it can also be concluded that one week after application of GA3, the starch fraction started to hydrolyse and increased total sugar content causing the tubers to sprout by breaking dormancy [13]. Gibberellic acid is a naturally occurring plant growth regulator which may cause a variety of effects, including the stimulation of seed germination by breaking seed dormancy. Gibberellins influence the dormancy of seeds, shoots, and other plant parts. In potato, a condition often physiological rest prevails from the time of tuber initiation until 6 to 12 weeks after harvest depending on varietal characteristics [14]. Similar conclusions were reported by Barani, et al. [13] and Mahmoodi, et al. [15].

B. Potassium Fertilizer Rate Effects

Concerning to the effect of potassium fertilizer rates on affected plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2014 and 2015 seasons, the results in Tables (1 and 2) clearly revealed that potassium fertilizer rates significantly affected plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2014 and 2015 seasons. The results indicated that increasing potassium fertilizer rates from 0 kgK_2O/ha to 172.5 kgK_2O/ha markedly increased plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2013/2014 and 2014/2015 seasons. Highest potassium fertilizer rates (172.5 kgK_2O/ha) produced the highest values of plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % in both 2013/2014 and 2014/2015 seasons. The corresponding data were 56.79, 32.57, 254.62, 37.19, 4.87, 466.9, 26.899, 5.37, 5.76, 17.52 and 14.18, respectively in the first season, and 57.15, 32.34, 254.93, 38.24, 4.89, 469.52, 27.052, 5.36, 5.80, 17.62 and 14.33, respectively in the second season. However, the lowest values of plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % were recorded from without potassium fertilization in both 2014 and 2015 seasons. It could be noticed that increasing potassium fertilizer rates from 0 kgK_2O/ha to 172.5 kgK_2O/ha significantly increased plant height, chlorophyll content, foliage dry weight g/plant and No. of tubers/plant, tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry matter and starch % by 3.6, 10.83, 9.02, 16.18, 6.69, 6.62, 11.47,7.11, 7.1 and 4.66 %, respectively as an average of both seasons. Potassium is critical for plant functioning, including enzyme activation, water and energy relations, assimilate translocation, and nitrogen and starch synthesis. Potassium was found to serve a vital role in photosynthesis by direct increasing in growth and leaf area index and hence CO2 assimilation and increasing the outward translocation of photosynthesis. Application of potassium fertilizers has significant and positive effect on the growth and yield of potato [16]. These results are in good agreement with those reported by Abu-Zinada [17]; Radwan, et al. [18]; Mohr and Tomasiewicz [19]; Manolov, et al. [20] and Abu-Zinada and Mousa [21].

Table-1. Mean of plant height, chlorophyll content, foliage fresh and dry weight g/plant and No. of tubers/plant as affected by soaking in GA3 concentrations and potassium fertilizer rates during 2014 and 2015 seasons.

Treatments	**Plant height**		**Chlorophyll content**		**Foliage fresh weight g/plant**		**Foliage dry weight g/plant**		**No. of tubers/plant**	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
A. Soaking in GA3 concentrations::										
0 ppm	53.47	53.68	28.55	28.63	246.59	246.43	36.92	36.97	3.55	3.56
10 ppm	54.86	55.16	29.18	29.85	252.21	252.50	37.83	37.88	4..16	4.19
20 ppm	56.42	56.57	30.77	30.96	256.34	256.39	38.45	38.45	4.79	4.82
30 ppm	58.59	58.92	31.01	32..07	258.08	258.15	38.71	38.72	5.43	5.45
F-test	*	*	*	*	*	*	*	*	*	*
L.S.D. 5%	0.049	0.59	0.50	0.29	1.52	0.26	0.03	0.04	0.05	0.07
B. Potassium fertilize rates:										
0 kg K_2O/ha	54.89	54.92	28.71	29.17	252.10	251.47	37.75	37.72	4.08	4.11
57.5 kg K_2O/ha	55.57	55.87	29.78	29.98	252.76	253.05	37.92	37.95	4.30	4.31
115 kg K_2O/ha	56.10	56.39	29.44	30.00	253.74	254.04	38.06	38.10	4.70	4.70
172.5 K_2O/ha	56.79	57.15	32.57	32.34	254.62	254.93	38.19	38.24	4.87	4.89
F-test	*	*	*	*	*	*	*	*	*	*
L.S.D. 5%	0.23	0.61	0.49	0.28	0.74	0.25	0.02	0.04	0.08	0.11
Interaction AXB										
F-test	N.S	N.S.	N.S	N.S.	*	*	N.S	N.S.	*	*

N. S.= Not significant, *= significant at 5%, **= significant at 1%

C. Interaction Effects

Results presented in Tables (1 and 2) clearly showed that the interaction between concentrations of GA3 and potassium fertilizer rates insignificantly affected plant height, chlorophyll content, foliage dry weight g/plant, tuber weight g/plant, TSS%, crude protein%, tuber dry matter % and starch % in both 2014 and 2015seasons.

Results presented in Tables (1 and 2) clearly showed that the interaction between concentrations of GA3 and potassium fertilizer rates significantly affected foliage fresh weight g/plant, number of tubers/plant and tuber yield t/ha in both 2014 and 2015 seasons. The results graphically illustrated in Fig 1, 2 and 3 clearly showed that the interaction between concentrations of GA3 and potassium fertilizer rates significantly affected foliage fresh weight g/plant (258.84 g/plant), and number of tubers/plant (5.83 tuber/plant) and tuber yield t/ha (29.148 t/ha), respectively were produced from soaking seed in highest GA3 concentration (30 ppm GA3) and highest potassium rate (172.5 kgK_2O/ha). Whilst, the lowest values of foliage fresh weight g/plant and No. of tubers/plant and tuber yield t/ha were obtained from without GA3 soaking and without potassium fertilization in 2014 season.

Table-2. Mean of tuber weight g/plant, tuber yield t/ha, TSS%, crude protein, tuber dry mater and starch % as affected by soaking in GA3 concentrations and potassium fertilizer rates during 2014 and 2015 seasons.

Treatments	**Tuber weight g/plant**		**Tuber yield t/ha**		**TSS%**		**Crude protein%**		**Tuber dry matter%**		**Starch%**	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
A. Soaking in GA3 concentrations::												
0 ppm	429.40	431.79	24.736	24.871	4.70	4.73	4.83	4.86	15.88	15.97	12.29	12.37
10 ppm	439.35	444.48	25.305	25.603	4.91	4.95	5.15	5.15	16.89	16.91	13.66	13.73
20 ppm	457.99	460.61	26.373	26.536	5.12	5.14	5.86	5.84	17.63	17.73	14.40	14.53
30 ppm	491.10	489.83	28.346	28.341	5.35	5.35	6.57	6.62	18.39	18.50	15.15	15.31
F-test	*	*	*	*	*	*	*	*	*	*	*	*
L.S.D. 5%	4.98	4.98	0.034	0.049	0.03	0.03	0.02	0.04	0.03	0.03	0.04	0.07
B. Potassium fertilize rates:												
0 kg K_2O/ha	435.36	438.37	25.113	25.250	4.77	4.81	5.36	5.39	16.86	16.87	13.53	13.65
57.5 kg K_2O/ha	454.08	454.16	26.150	26.256	4.85	4.88	5.58	5.59	17.11	17.21	13.77	13.85
115 kg K_2O/ha	461.50	464.22	26.601	26.743	5.11	5.14	5.66	5.69	17.31	17.41	14.01	14.09
172.5 K_2O/ha	466.90	469.52	26.899	27.052	5.37	5.36	5.76	5.80	17.52	17.62	14.18	14.33
F-test	*	*	*	*	*	*	*	*	*	*	*	*
L.S.D. 5%	11.98	4.61	0.028	0.037	0.04	0.03	0.03	0.02	0.03	0.02	0.04	0.07
Interaction AXB												
F-test	N.S	N.S.	*	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N. S.= Not significant, *= significant at 5%, **= significant at 1%

Regarding to the effect of the interaction between concentrations of GA3 and potassium fertilizer rates on chlorophyll content, foliage fresh and dry weight g/plant and number of tubers/plant and tuber yield t/ha in 2015 seasons, the results in Figs. 4, 5 and 6 clearly revealed that, foliage fresh weight g/plant and number of tubers/plant and tuber yield t/ha significantly affected by this interaction in 2015 season. The results clearly indicated that highest values of foliage fresh weight g/plant (259.16 g/plant), number of tubers/plant (5.86 tubers/plant) and tuber yield t/ha (29.306 t/ha) in season. Whilst, the lowest values of foliage fresh weight g/plant and number of tubers/plant and tuber yield t/ha were produced from without GA3 soaking and without potassium fertilization in 2015. Similar conclusion was reported by Manolov, et al. [20] and Abu-Zinada and Mousa [21].

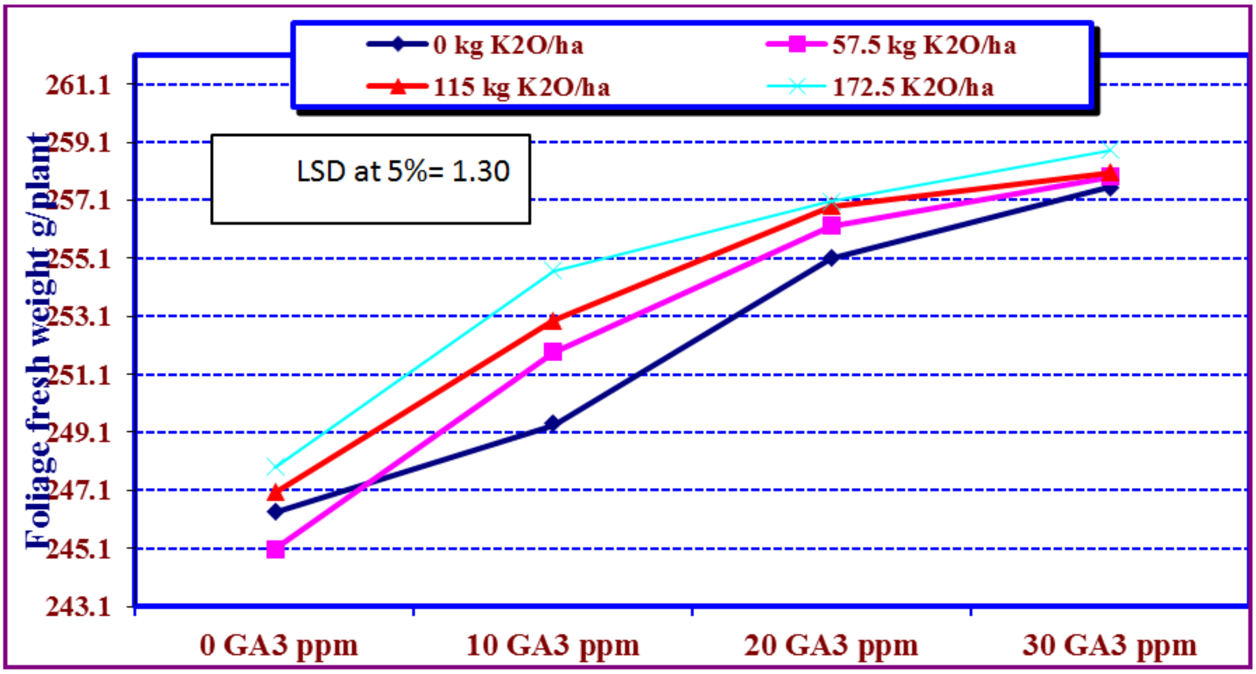

Fig-1. Means of foliage fresh weight g/plant as affected by the interaction between soaking in GA3 and potassium fertilizer rates during 2013/2014 season.

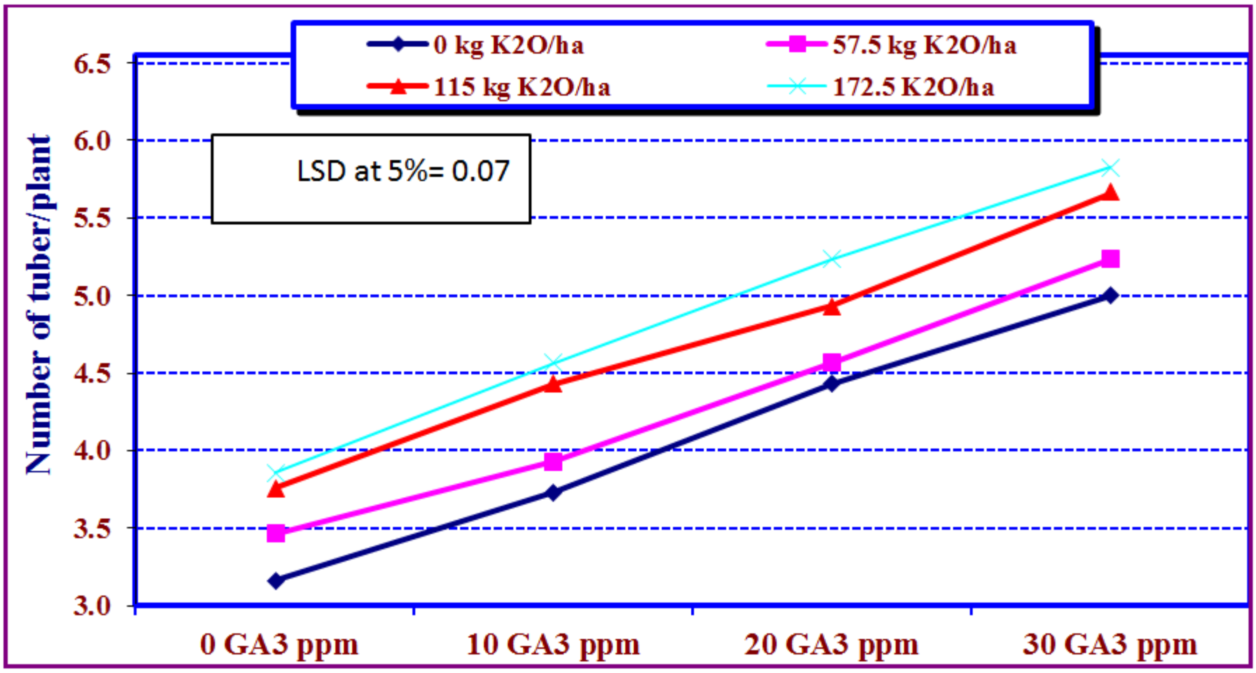

Fig-2. Means number of tuber/plant as affected by the interaction between soaking in GA3 and potassium fertilizer rates during 2013/2014 season.

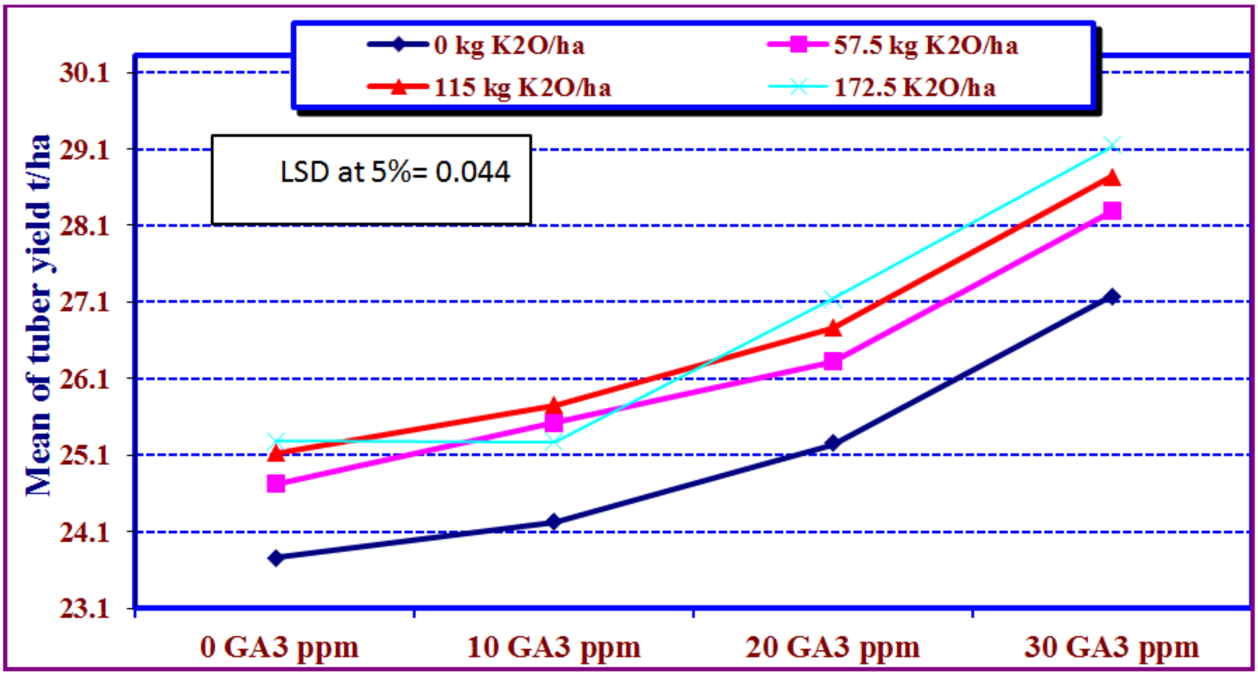

Fig-3. Mean of tuber yield t/ha as affected by the interaction between soaking in GA3 and potassium fertilizer rates during 2013/2014 season.

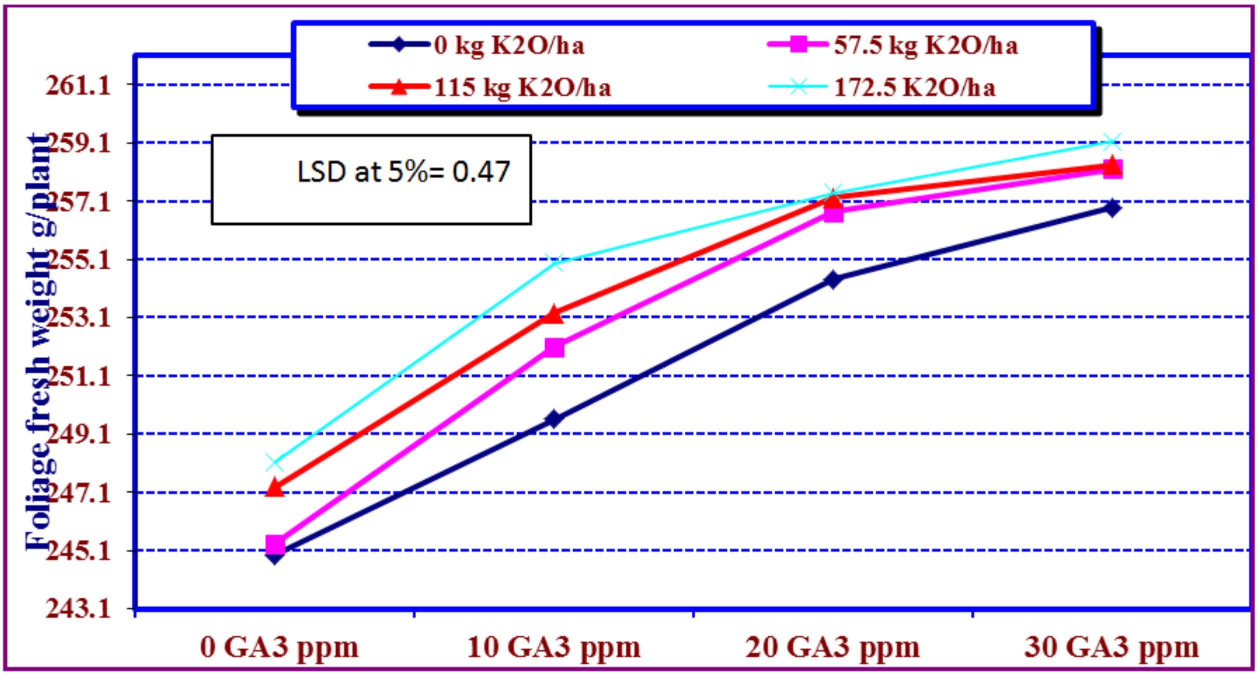

Fig-4. Means of foliage fresh weight g/plant as affected by the interaction between soaking in GA3 and potassium fertilizer rates during 2014/2015 season.

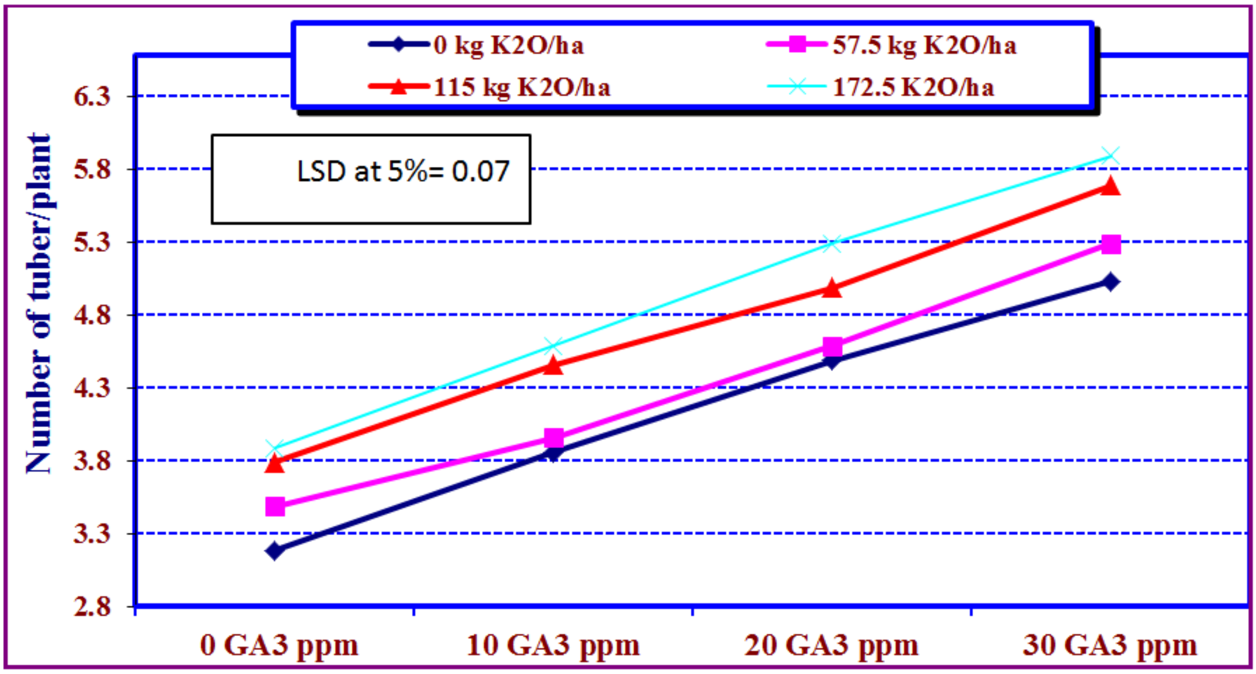

Fig-5. Mean number of tuber/plant as affected by the interaction between soaking in GA3 and potassium fertilizer rates during 2014/2015 season.

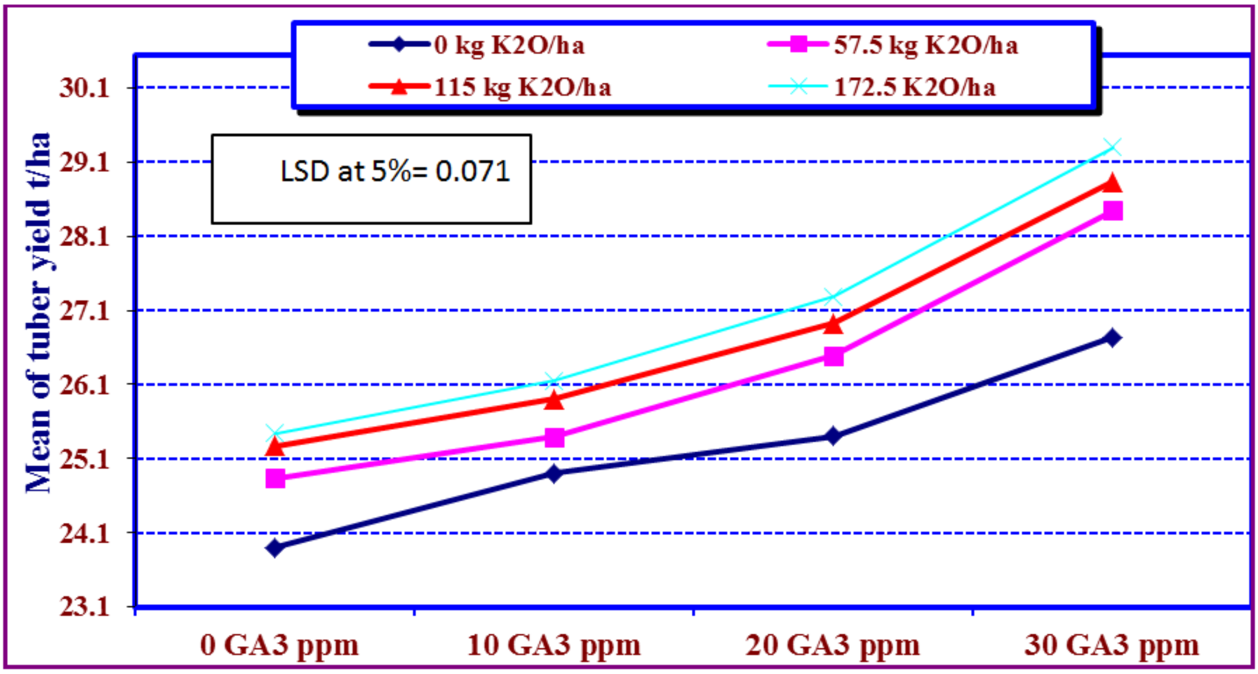

Fig-6. Mean of tuber yield t/ha as affected by the interaction between soaking in GA3 and potassium fertilizer rates during 2014/2015 season.

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