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# Beneficial Effects of Humic Substances on Soil Fertility to Fertigated Potato Grown on Sandy Soil

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**Abstract:** This study was performed to evaluate the application of humic substances with either single or combined N, P and K fertilizers through drip irrigation system on availability of NPK nutrients at 0-15, 15-30 and 30-45cm soil layers, tuber quantity, quality and nutritional status of fertigated potato grown on sandy soils. So, field experiment was carried out at the experimental farm of the Agricultural Research Station, National Research Centre, El-Nubaria district, Egypt during the summer of 2008 season. The experiment was set up in split plot design with three replicates, main treatments were assigned fertilizer types, i.e. single and combined fertilizers, while sub treatments were presented 4 treatments as follow, 100% of recommended chemical N, P and K fertilizer doses (control) and humic substances was injected with 100, 75 and 50% of N, P and K fertilizers through drip irrigation system. Data revealed that fertigation of combined NPK fertilizer was more efficient than single N, P and K fertilizers on improving tuber yield quantity, quality indicators and nutritional status of potato crop, as well as soil fertility after harvesting at all soil layers. Additional rates of fertigation significantly increased the tuber yields, tuber quality indicators, NPK nutrient concentrations in potato tissues and fertilizer use efficiency (kg yield kgG[1] NPK fertilizer) except for specific gravity (g $cm^{-3}$) and TSS (%) in tubers. Moreover, humic substances added with NPK fertigation treatments resulted in lesser leaching N, K to deeper layer and higher available P to deeper layer of soil. Also, the tuber yield was increased by 16.47% with addition of humic substances comparing to the recommended rate solely. The most considered treatments for enhancing tuber yield, quality indicators, nutritional status of potato crop and soil fertility compared to the recommended dose of N, P and K (control) was addition humic substances with 100% fertigation followed by 75% fertigation of combined NPK fertilizer with slightly difference between such two treatments. There is a parallel trend was observed between the addition of humic substances with 75% fertigation treatment of combined NPK fertilizer and the addition of 100% fertigation treatment solely (recommended rate).

**Key words:** Humic substance % Fertigation % Single and Combined NPK fertilizer % Soil fertility % Potato % Sandy soil

## INTRODUCTION

Most of our provinces are with poor soils, degraded soils and soils with problems of fertility with larger or smaller areas. In these regions crop yields are low and life of people faces difficulties. The basis measures of soil improvement are required to overcome crop yield limiting factors and on this basis to apply a reasonable fertilization regime. Sandy soils are the soils with light texture and poor in nutrient with low CEC, therefore applied fertilizers can easily be leached. So, many researchers indicated to the beneficial effect of fertigation that increasing the efficiency of nutrients utilization under drip irrigation system [1, 2].

Generally, crop response to fertilizer application through drip irrigation has been excellent and frequent nutrient applications have improved the fertilizer-use efficiency [3]. Furthermore, in sandy loam soil, [4] revealed that fertigation resulted in lesser leaching of $NO_3$-N and K to deeper layer of soil. Humic substances are a heterogeneous mixture of naturally occurring organic materials those arise from the decay of plant and animal residues. These organic materials contain carbon, which serves as a food source for soil organisms such as bacteria, algae, fungi and earthworms. These soil organisms break the chemical bonds in the residues as they digest the carbon. The remaining by-products serve as building blocks of humic substances, which are not

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easily decomposed by soil organisms [5] and this will decrease nutrients leaching with irrigation water and so increase fertilizers use efficiency [6]. In this concern, [7] found that application of humic substances through drip irrigation enhanced tubers yield quantity, starch content and total soluble solids and this application associated with the decrease of nutrients leaching, which was reflected on increasing macro-and micronutrients concentration in potato tubers, as well as increasing concentration of these nutrients in soil after tubers harvesting. Potato (*Solanum tuberosum* L.) is one of the most important vegetables in Egypt. It gained a considerable importance as an export crop to European markets and one of the national income resources [8]. Therefore, in this research we have evaluated the beneficial effect of humic substances added with either single or combined N, P and K fertilizers through drip irrigation system on tuber quantity, quality and nutritional status of potato crop as well as NPK nutrients availability at 0-15, 15-30 and 30-45cm soil layers under sandy soil conditions.

## MATERIALS AND METHODS

Fertigation experiment was conducted at the Agricultural Research Station, National Research Centre, El-Nubaria district, Egypt (latitude of 30° 30°N and longitude of 30° 20°E) during the growing season of summer 2008 to study the effect of humic substances addition with either single or combined NPK fertilizers through drip irrigation system on mobility of NPK nutrients at 0-15, 15-30 and 30-45cm soil layers, tuber quantity, quality and nutritional status of fertigated potato grown on sandy soils. The used experimental design was split plot design with three replicates. Main plots were assigned to the two fertilizer types, i.e. single and combined NPK fertilizers. While, sub treatments were presented 4 treatments were examined as follow, 100% of recommended chemical NPK fertilizer dose (control), which are 450 N, 85 $P_2O_5$ and 200 $K_2O$ kg ha$^{-1}$ as recommended by Ministry of Agriculture and humic substances were injected with 100%, 75% and 50% of N, P and K fertilizers through drip irrigation system, respectively. Two fertilizer types i.e., single and combined of N, P and K fertilizes and humic substances were produced from Egyptian Fertilizer Development Centre, El-Mansoura. The chemical analysis of humic substances is shown in Table 2.

The area of each plot was 100 m$^2$; hence, the total area of the field experiment was 1800 m$^2$. Plants row spacing was 0.75 m and the distance between each plant was 0.25 m. Soil samples i.e. 0-15, 15-30 and 30-45cm were collected by auger and these were air-dried, crushed and passed through a 2-mm sieve and preserved for analyses. Some physical and chemical properties at different depths of El-Noubaria soil illustrated in Table 1 according to Hesse [9].

Table 1: Some physical and chemical properties at different depths of El-Noubaria soil

| | | Soil depths (cm) | | |
|---|---|---|---|---|
| Soil properties | | 0-15 | 15-30 | 30-45 |
| Physical properties | | | | |
| Particle size | Coarse sand | 56.99 | 57.18 | 48.08 |
| Distribution | Fine Sand | 29.56 | 30.12 | 42.18 |
| | Silt | 10.12 | 9.85 | 8.10 |
| | Clay | 3.33 | 2.85 | 1.64 |
| | Soil texture | Sand | Sand | Sand |
| | Soil Taxonomy | *Entisol-Typic Torripsamments* | | |
| Chemical properties | | | | |
| Calcium carbonate,% | 6.06 | 2.14 | 5.00 | |
| pH | 8.6 | 8.7 | 8.7 | |
| EC(dS m$^{-1}$) | 0.25 | 0.30 | 0.42 | |
| Soluble cations (meq l$^{-1}$) | $Ca^{++}$ | 0.94 | 1.40 | 1.91 |
| | $Mg^{++}$ | 0.62 | 0.65 | 0.85 |
| | $Na^{+}$ | 0.52 | 0.50 | 1.00 |
| | $K^{+}$ | 0.37 | 0.45 | 0.44 |
| Soluble anions (meq l$^{-1}$) | $CO_3^{--}$ | -- | -- | -- |
| | $HCO_3^{-}$ | 0.10 | 0.10 | 0.1 |
| | $Cl^{-}$ | 0.64 | 0.91 | 2.33 |
| | $SO_4^{--}$ | 1.70 | 1.99 | 2.01 |
| Available nutrients (mg kg$^{-1}$ soil) | N | 29.02 | 24.00 | 16.30 |
| | P | 4.00 | 4.00 | 3.08 |
| | K | 94 | 65 | 56 |

Table 2: Chemical properties of humic substances.

| | | | Macronutrients (%) | | | Micronutrients (mg kg$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|
| pH | EC dSm$^{-1}$ | OM% | N | P | K | Zn | Fe | Mn |
| 7.83 | 0.94 | 68 | 2.09 | 0.15 | 3.42 | 258 | 415 | 214 |

For combined fertilizers, the fertilizer in the form of (20N-10P-5K) according to the treatments of 100%, 100% + humic substances, 75% + humic substances and 50% of recommended NPK fertilizer + humic substances injected through drip irrigation system from the 2$^{nd}$ week until the 7$^{th}$ week of the plant growth stage. While, the fertilizer (10N-3P-36K) which contains high concentration of K nutrient was applied according to the previous treatments at the 8$^{th}$ week until the end of fertigation programme. Single N, P and K fertilizers supplied with drip fertigation system along the growing season, N was added in the form of ammonium nitrate (33.5%N) and phosphorus as phosphoric acid (50% $P_2O_5$), while potassium was added in the form of potassium sulfate (48% $K_2O$). The nitrogen fertilizer was injected at the rates 450, 450, 337.5 and 225 kg N ha$^{-1}$) N Kg ha$^{-1}$, respectively divided into 10 portions weekly starting from the second week after planting. Meanwhile, the phosphorus was injected at rates 85, 85, 63.5 and 42.5 $P_2O_5$ Kg ha$^{-1}$ of phosphoric acid. After three weeks from planting, the rest of the total potassium requirement (200, 200, 150 and 100 $K_2O$ Kg ha$^{-1}$) of potassium sulfate, respectively were injected in 7 doses during 7 weeks. After 125 days of fertilization programme, a random sample of three plants from each plot was chosen and prepared for chemical analysis. Fresh tubers yield was calculated as (Mg ha$^{-1}$). Specific gravity of tubers was calculated as (g cm$^{-3}$) according to the methods described by Smith [10]. Total soluble solids percentage (TSS) was measured in fresh tubers using hand refractmeter method and the starch content was calculated according to the formula of Burton [11]:

$$\text{Starch (\%)} = 17.546+199.07x \text{ (S.g.G}^{-1}.0988).$$

To determine N, P and K concentrations in both foliage and tuber tissues of potato, samples were taken from each plot, dried at 70° and grounded using stainless steel equipments. From each sample 0.2 g was digested using 5 cm$^3$ from the mixture of sulfuric ($H_2SO_4$) and perchloric ($HClO_4$) acids (1:1) as described by Cottenie [12]. After potato harvesting, soil samples were taken at three depths of 0-15, 15-30 and 30-45cm, respectively. The same procedures of soil analysis before cultivation were carried out to study NPK distribution at three soil depths under investigated treatments as mentioned by Hesse [9]. Fertilizer-use efficiency was worked out as a factor of total yield by quantity of fertilizer applied and expressed as a ratio. All data were statistically analyzed according to the technique of analysis of variance (ANOVA) published by Gomez and Gomez [13].

## RESULTS AND DISCUSSION

**NPK distribution in soil:** A glance of the following figures, it could noticed that additional rates of fertigation treatments had a significant effect on soil N, P and K remained at three soil layers i.e., 0-15, 15-30 and 30-45cm, respectively after potato harvesting. Injection of NPK fertilizer as a combined form increased available soil-N, P and K more than a single form. Generally, addition of humic substances jointly with N, P and K either single or combined fertilizer form improving the soil fertility status at different soil layers.

The highest available N was 70 and 84.59 mg kg soil$^{-1}$ observed with addition of humic substances to 100% NPK through drip fertigation system either single or combined fertilizer form at 15-30 cm soil depth, respectively. While, at 30-45cm subsurface layer, the lowest available N in soil was 25 and 30 mg kg soil$^{-1}$ occurred with 50% NPK fertigation plus humic substances in single and combined fertilizer forms, respectively. It is worthy to note that the additional of humic substances may be improving soil physical and biological properties, which are reflected generally, on soil fertility status and thus the dynamic changes of ($NH^+_4$ + $NO^-_3$)-N in the upper 30 cm of soil could be influenced, to a great extent. Also, the combined application of chemical fertilizers and humic substances could be an effective method to increase the plant availability of N in soils [14]. Available P distribution at all soil layers was at a higher level except at a deeper depth of 30-45 cm (Fig. 2a&b). The level of available P was markedly higher in 0-15 cm (10.5 mg kg soil$^{-1}$), 15-30cm (10.6 mg kg soil$^{-1}$) and 30-45cmdepth (6.3 mg kg soil$^{-1}$) in addition of humic substances to 100% combined NPK fertilizer form compared to other treatments because the addition of humics to the soil increases the recovery of Olsen P in all soils tested, except in those with very high Na content [15].

In summary, from our findings, the same values of available P in soil occurred with addition of humic substances to 75% NPK in a combined fertilizer form approximately as compared to 100% application of N, P

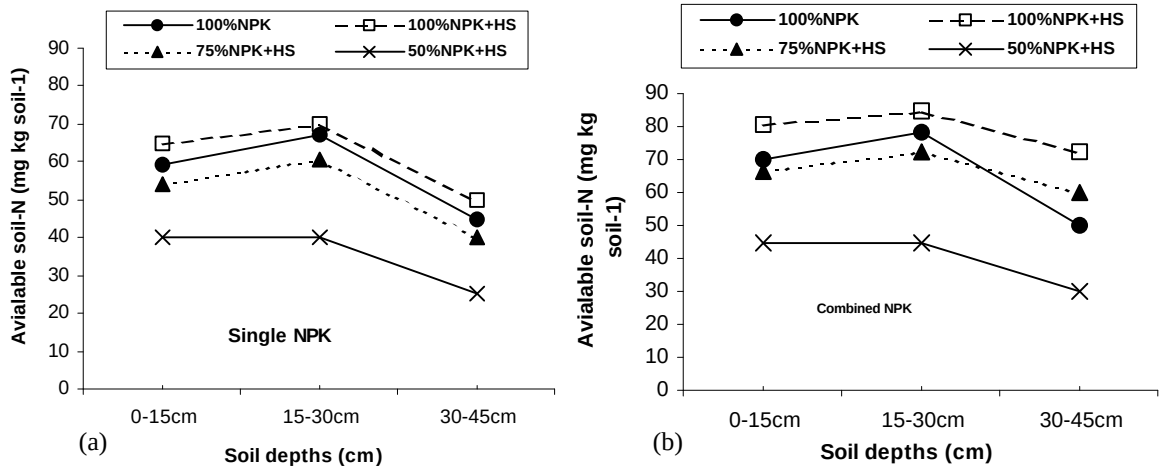


Fig. 1a,b: Available soil-N (mg kgG[1] soil) at different soil depths as affected by humic substances and fertigation treatments

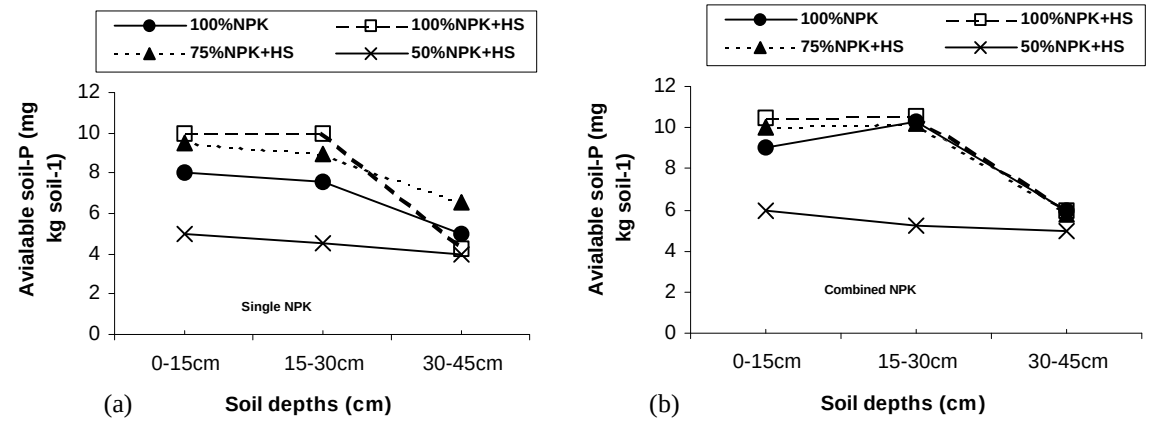


Fig. 2a,b: Available soil-P (mg $kg^{-1}$ soil) at different soil depths as affected by humic substances and fertigation treatments

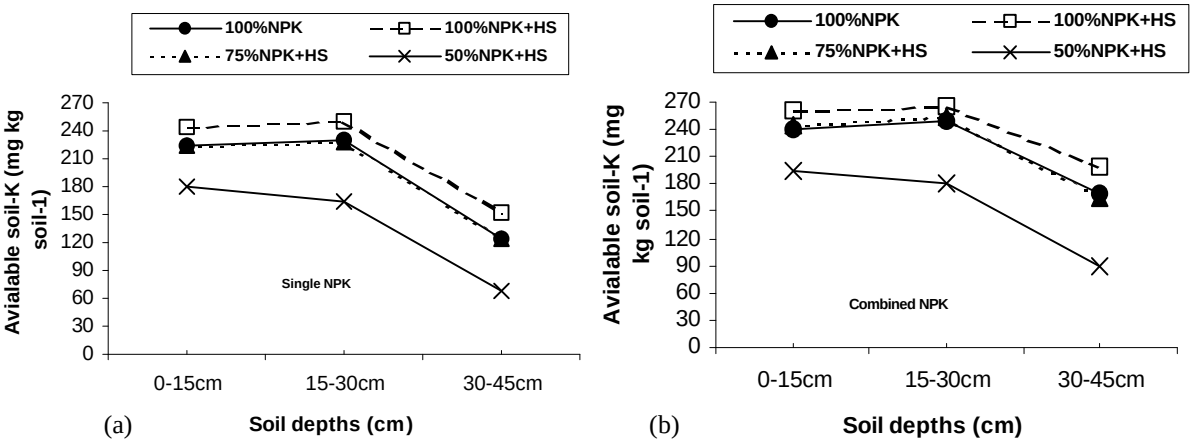


Fig. 3a,b: Available soil-K (mg $kg^{-1}$ soil) at different soil depths as affected by humic substances and fertigation treatments

Table 3: The combined effect of fertilizer types and fertigation treatments on yield and yield components and fertilizer use efficiency

| Treatments | No. of tubers/plant | Tuber yield (Mg ha$^{-1}$) Total | Marketable | Unmarketable | FUE Kg yield kg$^{-1}$ NPK fertilizer) |
|---|---|---|---|---|---|
| Mg ha$^{-1}$ | | | | | |
| Fertilizer types | | | | | |
| Single | 5.06 | 40.06 | 37.39 | 2.66 | 50.14 |
| Combined | 5.44 | 43.84 | 41.52 | 2.32 | 55.89 |
| F test | NS | * | * | NS | * |
| Fertigation treatments plus humic substances | | | | | |
| 100% | 5.99ab[2] | 43.37b | 41.45b | 1.92d | 54.54b |
| 100% + HS[1] | 6.29a | 47.77a | 44.94a | 2.83b | 59.13a |
| 75% + HS | 5.03b | 43.42c | 41.47c | 2.92a | 50.16c |
| 50% + HS | 3.70c | 35.60d | 33.31d | 2.29c | 43.83d |
| Fertilizer types x ferrtigation treatments plus humic substances | | | | | |
| Single | 100% | 5.85c | 41.14c | 38.74cd | 2.40c | 50.97c |
| | 100% + HS | 6.00b | 46.30b | 43.32c | 2.98a | 57.00b |
| | 75% + HS | 4.85e | 41.16c | 38.75cd | 2.41bc | 50.99c |
| | 50% + HS | 3.55f | 34.01e | 31.61e | 2.40c | 41.59e |
| Combined | 100% | 6.12ab | 45.60b | 44.16b | 1.44e | 58.11ab |
| | 100% + HS | 6.58a | 49.25a | 46.56a | 2.69b | 61.26a |
| | 75% + HS | 5.20d | 45.67b | 44.18b | 1.49e | 58.13ab |
| | 50% + HS | 3.85ef | 37.20d | 35.02d | 2.18d | 46.07d |

[1], Humic substances, [2], Means sharing similar letter (s) do not differ significantly.

and K solely as shown in Fig. 2a andb. Similarly, higher available K was observed at 10-15cm and 15-30cm soil layers except at 30-45cm as affected by additional rates of NPK fertigation either in a single or combined fertilizer form (Fig. 3 a and b).

Meanwhile, higher values of available K were higher with application of NPK fertilizer in a combined form more than in a single form at three soil layers. Moreover, addition of humic substances to mineral fertilizers maximized available K in soil and when humic substances injected with 100%NPK fertilizer, available K values were 260, 265 and 200 g kg soil$^{-1}$ higher more than application of 100% NPK fertilizer solely at all soil layers. On the other hand, parallel trend may be drawn between the K mobilizing effects of humic substances plus 75%NPK and 100% NPK fertigation solely. It is well established that when humic acid applied to sandy soils, it adds essential organic material necessary for water retention thus improving root growth and enhancing the sandy soil's ability to retain and not leach out vital plant nutrients [14, 16].

**Tuber Yield and Yield components:** Data illustrated in Table 3 revealed that NPK fertigation in a single or a combined fertilizer form had significantly influenced on total, marketable tuber yields (Mg ha$^{-1}$) except for number of tubers/plant and unmarketable tuber yield (Mg ha$^{-1}$). Moreover, additional rates of NPK fertigation had significantly increased No. of tubers plant$^{-1}$, tuber yields (Mg ha$^{-1}$). Addition of humic substances to the NPK fertilizer tended to increase No. of tubers/plant, tuber yield and its components at both 100% and 75% NPK in single or combined fertilizer forms followed by the injection of these fertilizers solely.

The highest means of marketable tuber yield was 46.56 Mg ha$^{-1}$ produced from the addition of humic substances to 100% fertigation as compared to the other treatments. The tuber yield in Table 3, showing an average increase in total yield of 16.47% with humic substances addition to 100% NPK fertilizer as combined form through drip irrigation system over 100% NPK fertilizer treatment solely (recommended rate) as a single form. These results could be attributed to the improvement of the moisture retention and nutrient supply potentials of sandy soils after humic substances application [7, 17, 18].

**Fertilizer Use Efficiency (kg yield kg$^{-1}$ NPK fertilizer):** Fertilizer-use efficiency was significantly superior in all the treatments where either single or combined fertilizer injected through drip irrigated system except for 50%NPK fertigation treatment (Table 3). This was due to better

Table 4: The combined effect of fertilizer types and fertigation treatments plus humic substances on tuber quality of potato plants

| Treatments | Specific gravity g $cm^{-3}$ | TSS % | Starch % | Protein % |
|---|---|---|---|---|
| Fertilizer types | | | | |
| Single | 1.09 | 5.31 | 13.81 | 11.33 |
| Combined | 1.09 | 5.37 | 15.26 | 12.44 |
| F test | NS | NS | * | * |
| Fertigation treatments plus humic substances | | | | |
| 100% | 1.08a | 5.07a | 13.81ab | 11.50c |
| 100% + HS[1] | 1.09a | 5.40a | 14.25ab | 13.13a |
| 75% + HS | 1.10a | 5.40a | 16.11a | 12.13b |
| 50% + HS | 1.08a | 5.42a | 14.00b | 10.78d |
| Fertilizer types x ferrtigation treatments plus humic substances | | | | |
| Single 100% | 1.06a | 5.03b | 10.50b | 10.81d |
| 100% + HS | 1.08a | 5.20ab | 14.46a | 12.50b |
| 75% + HS | 1.11a | 5.43ab | 15.44a | 10.75d |
| 50% + HS | 1.09a | 5.37ab | 14.87a | 11.44cd |
| Combined 100% | 1.10a | 5.10ab | 17.12a | 12.19c |
| 100% + HS | 1.10a | 5.43ab | 14.03a | 13.75a |
| 75% + HS | 1.09a | 5.23ab | 16.79a | 12.88b |
| 50% + HS | 1.08a | 5.50a | 13.14ab | 10.94cd |

[1], Humic substances, [2], Means sharing similar letter (s) do not differ significantly.

Table 5: The combined effect of fertilizer types and fertigation treatments plus humic substances on nutritional status of potato foliage and tuber tissues

| | Foliage | | | Tuber | | |
|---|---|---|---|---|---|---|
| Treatments | N | P | K | N | P | K |
| | …%… | | | | | |
| Fertilizer types | | | | | | |
| Single | 2.53 | 0.28 | 1.69 | 1.81 | 0.22 | 2.72 |
| Combined | 2.91 | 0.30 | 1.78 | 1.99 | 0.25 | 3.07 |
| F test | * | * | * | * | * | NS |
| Fertigation treatments plus humic substances | | | | | | |
| 100% | 2.63b | 0.29b | 1.76c | 1.84c | 0.22b | 2.89ab |
| 100% + HS[1] | 3.31a | 0.32a | 1.98a | 2.10a | 0.26a | 2.94a |
| 75% + HS | 2.68b | 0.30ab | 1.80b | 1.94b | 0.22b | 2.94a |
| 50% + HS | 2.27c | 0.25c | 1.40d | 1.73d | 0.23b | 2.82b |
| Fertilizer types x fertigation treatments plus humic substances | | | | | | |
| Single 100% | 2.30d | 0.28b | 1.70c | 1.73d | 0.19c | 2.65d |
| 100% + HS | 3.28ab | 0.31a | 1.97a | 2.00b | 0.26a | 2.84c |
| 75% + HS | 2.30a | 0.29ab | 1.75bc | 1.82cd | 0.19c | 2.67d |
| 50% + HS | 2.25d | 0.23d | 1.33e | 1.70e | 0.23b | 2.73cd |
| Combined 100% | 2.96c | 0.29ab | 1.82b | 1.95c | 0.25a | 3.12ab |
| 100% + HS | 3.33a | 0.33a | 1.99a | 2.20a | 0.26a | 3.04b |
| 75% + HS | 3.05b | 0.30ab | 1.85ab | 2.06ab | 0.25a | 3.20a |
| 50% + HS | 2.29d | 0.27c | 1.46d | 1.75cd | 0.23b | 2.91bc |

availability of moisture and nutrients throughout the growth stages in drip fertigation system leading to better uptake of nutrients and production of potato tubers [14]. FUE was significantly higher with addition of humic substances to 100% NPK fertilizer (59.13 kg $kg^{-1}$ NPK) compared to 100% fertigation only (54.54 kg), 75% plus humic substances fertigation (50.16 kg) and 50% rate fertigation plus humic substances (43.38kg).Regardless, addition of humic substances to 100% and 75% NPK fertigation resulted in further increases FUE greater than fertigation of 100% NPK solely. Accordingly, humic substances should be used to decrease the chemical fertilizer negative effects on soil and plant growth.

**Tuber quality:** Comparing with the single fertilizer injected through drip fertigation system, combined fertilizer significantly improved the tuber quality indicators (Table 4).

Similarly, the same trend was observed on obvious tuber quality indicators with the addition of humic substances to NPK fertigation treatments. It is worthy to note that addition of humic substances to 75% fertigation treatment resulted in further increase in tuber quality indicators followed by 100% fertigation and 50% fertigation treatments, respectively. With respect to the interaction effects, statistical analysis clear that the tuber quality indicators significantly affected by the application of humic substances to fertigation treatments in combination with single or combined fertilizers except for specific gravity (g $cm^{-3}$) but generally the effects were negligible. Whatever, improving potato yield could be related to the increasing of soil aggregates due to the high content of organic matter in humic substances application [7, 19]. The formation of these aggregates could protect potato tubers to be covered under soil at all growth stages and this could improve tubers quality.

**Nutritional status of plant:** As shown in Table 5, the differences in means of nutrients concentration in potato tuber and foliage tissues with addition of humic substances fertigation were significant ($P < 0.05$). The addition of NPK fertilizer as a combined fertilizer produced the maximum concentration of nutrients in both tuber and foliage of potato plants comparing with single fertilizer. Concerning the effect of addition of humic substances to fertigation treatments, the same Table shows that addition of humic substances to fertigation treatments positively increased nutrients concentration in potato organs comparing with 100% fertigation treatment solely. The highest values of these nutrients were occurred with 100%fertigation plus humic substances followed by 75% fertigation plus humic substances, 100% fertigation alone and finally 50% fertigation plus humic substances, respectively.

Similarly, higher tuber and foliage N, P and K concentrations with the addition of mineral fertilizer as a combined form, with further increases resulting from the addition of humic substances. Highest values of N, P and K were 3.33, 0.33 and 1.99% in foliage occurred with addition of humic substances to 100%fertigation of combined NPK fertilizer as compared to the others. On the contrast, the highest values of N and P of 2.20 and 0.26% with addition of humic substances to 100% fertigation of combined fertilizer and 3.20% with addition of humic substances to 75% fertigation of the same fertilizer type. This could be attributed to the strengthening of rooting system, which was reflected in increasing nutrients uptake by plants [20]. Moreover, the role of humic substances application is mainly related to the enrichment of nutrients uptake where these humic substances increases soil's cation exchange capacity (ability to hold and release cations such as $K^+$, $Ca^{2+}$, or $NH_4^+$) and can also form aqueous complexes with micronutrients [21]. These effects were associated with increasing nutrients concentration in potato tubers and foliage tissues.

## CONCLUSION

This study has concluded that addition of humic substances to NPK fertilizer through drip irrigation system resulted in lesser leaching N, K to deeper layer and higher available P to deeper layer of soil. There is a parallel trend was observed between the addition of humic substances to 75% fertigation treatment of combined NPK fertilizer and the addition of 100% fertigation treatment solely (recommended rate). Accordingly, our results ensure the necessary of partial replacement of chemical NPK fertilizer by the addition of more economical and safe organic materials in improving potato tubers under sandy soil conditions.

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