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EFFECT OF RICE STRAW AND APPLICATIONS OF POTASSIUM SILICATE, POTASSIUM HUMATE AND SEAWEED EXTRACT ON GROWTH AND SOME MACRONUTRIENTS OF SWEET PEPPER PLANTS UNDER IRRIGATION DEFICIT

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ABSTRACT

Field experiment was conducted during the two growing seasons of 2013-2014 and 2014-2015, in a private farm at El-Salheya El-Gedida City, Ismailia Governorate, Egypt, to investigate the effect of rice straw (RS) as alternative to sandy soil (SS) and drenching applications of potassium humate (K_2-HA) at 2 g/l, potassium silicate (K_2SiO_3) at 5 g/l, and seaweed extract (SWE) at 0.5 g/l on improving growth of sweet pepper (*capsicum annuum* L.) plants under deficit irrigation every 2 (I_2), 3 (I_3) and 4 (I_4) days in addition to daily irrigation (I_1) as control. Plant samples were taken at 90 days after transplanting to record leaf area, shoot fresh and dry weights, in addition to, determination of leaf relative water content (LRWC), concentrations of N, P, K and Ca. Mean values of drenching applications showed significant increase in the growth parameters ;shoot fresh and dry weights, leaf area, LRWC, as well as, concentrations of N, P and Ca in the two seasons comparing to untreated control and the best results were due to K_2-HA followed by SWE then K_2SiO_3. The highest concentration of K was obtained by K_2SiO_3 followed by K_2-HA then SWE. Plants were grown on RS showed significant increase in LRWC comparing to plants were grown on SS. Plants were applied with I_2+ K_2-HA+ SS showed the highest significant value of shoot fresh weight, shoot dry weight, leaf area, N, P and Ca concentrations followed by I_2+SWE+SScomparing to control plants applied with I_1+ SS without drenching applications. Plants were grown on RS showed significant increase in growth parameters comparing with control plants but less than those were grown on SS. The best results were achieved by I_3 + K_2-HA+ RS, I_3 + SWE+ RS, I_4 + K_2-HA+ RS. Plants were grown on rice strawunderI_3 irrigation and applied with K_2-HA or SWE showed significant increase in N, P and Ca concentrations, while, under I_4 irrigation an increase in N and P concentrations was obtained by K_2-HA.The highest concentrations of k were observed with plants grown on SS under the highest level of irrigation deficit I_4 by K_2SiO_3.It could be concluded from the present study that rice straw could alleviate the negative effect of low water supply and applications of K_2-HA and SWE are recommended for enhancing sweet pepper growth and nutrient elements uptake under water deficit conditions.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is a member of the solanaceous fruity vegetables group. It is one of the most important, popular and favorite vegetable crops cultivated in Egypt for local consumption and exportation **(El-Bassiony et al 2010)**Sweet pepper is consumed both as fresh and dehydrated spices **(Bosland and Vostava, 2000)**. Pepper is a good source of vitamins A, C, E, B1, and B2, potassium, phosphorus and calcium. Moreover, it is one of the valuable medicinal plants in pharmaceutical industries because of high amounts of antioxidant (**Aminifard et al 2012**).

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The relative amount of water available to agriculture is declining worldwide due to the rapid population growth and the greater incidence of drought in recent years caused by climate change and different human activities. Competing agricultural, municipal and industrial water usage will eventually threaten food security**(UNWWAP, 2003 and Bank, 2006).** Continued successful management of the limited amount of water available for agricultural uses depends upon better agronomic practices and enhanced understandings of water productivity, defined as the crop productivity output per unit of water consumed **(Howell et al 1998 and Jones, 2004)**.

Rice straw represents an important summer crop by-product in Egypt. The high amount of rice straw that produced (more than 5 million tons every year from the rice fields), there is no organized practical use for this waste until now, which it causes serious pollution when disposed by burning. The very cheap price and the major components of rice straw are silica, lignin and hemicelluloses, which are not attractive or favorable for soil fungi or nematodes, it could represent a good substrate for sowing instead of natural infested soil under open field conditions**(Abdet-Sattar et al 2008)**.**El-Sayed et al (2015)** demonstrated that rice straw could be recommended as a growing substrate in replacing naturally infested soil, as it can improve the production of pepper plants under greenhouse conditions in Egypt, with saving 35-38% of irrigation water.

Silicon is the second most abundant element in the earth's surface and is one of the important elements that form clay minerals structure in soils and is known as a useful element for plants **(Epstein, 1999)**. The amount of silicon uptake and collection by plants is variable between 0.1 to 10 percent of dry weight. Today, silicon is not classified as an essential element for plants but its beneficial effects has been observed in a wide range of plant species **(Epstein, 1994 and Ma & Yamaji, 2006)**. High silica uptake has been shown to improve drought resistance, increase resistance to fungi and other pathogens, and increase plant growth rate and yield **(Marschner, 1995; Piorr, 1986 and Belanger et al 1995).** The role of Si has proven to be in response to different abiotic and biotic stress. Meaningfully, increasing resistance to diseases and pathogens, metal toxicities, salinity and drought stresses are some of the most important functions of this element. Indeed, protecting plants against extremely high or low temperature needed for nodule configuration, as well as beneficial effect over the mineral composition and enzyme activities of plants are other advantages **(Epstein, 2001).**

Karakurt et al (2009) reported that potassium humate (K_2-HA) can be used as a non-expensive source for potassium and it could be used as soil dressing, drenching or foliar applications. It was already subjected to many studies in various areas of agriculture. The mechanism of humate material in promoting plant growth is not completely known. It was reported by many researchers that K_2-HA application increased the plant growth, nutrient uptake and plant yield and quality as well. Also, they reported that K_2-HA application led to increasing and improving pepper plant growth parameters. **Nardi et al (2002)** reported that the simulative effect of K_2-HA in enhancing fruit characteristics may be attributed to that some plant hormone like substances seem to be present in the humic substances.

The role of seaweed extract (SWE) in alleviating the effect of abiotic stress and enhancing plant growth have been mentioned by many workers on cucumber, soybean, fenugreek and wheat **(Wang, et al 2005 and Chernane, 2015)**. The improvement in vegetative growth characters induced by seaweed extracts was attributed to the role of seaweed extracts as bio-stimulants for plant growth and development because of the presence of trace elements, organic substances like amino acids and plant growth regulators such as auxin, cytokinins and gibberellins which improve vegetative growth **(Abdel-Maguid et al 2004 and El Moniem & Abd-Allah, 2008).**

Therefore, the present study was conducted to investigate the effect of growing media (compacted rice straw bales as soil alternative), drenching applications of potassium silicate, potassium humate and seaweed extract, on growth and concentration of some macronutrients of sweet pepper plants grown under different levels of irrigation deficit.

MATERIAL AND METHODS

Field experiment was conducted during the two growing seasons of 2013-2014 and 2014-2015, in a private farm (30°39'N, 32°06'E) at El-Salheya El-Gedida City, Ismailia Governorate, Egypt, to investigate the effect of rice straw as soil alternative and drenching applications of potassium silicate (K_2SiO_3), potassium humate (K_2-HA), and seaweed extract (SWE) on improving growth and productivity of sweet pepper under deficit irrigation.

1. Preparation of transplants and rice straw bales (soil alternative)

1.1. Transplants preparation

Imported hybrid seeds of sweet pepper plant (*capsicum annuum* L.), "Masillia" hybrid was purchased from Rijk Zwaan company. Seeds were sown in the shading screen nursery in July 1^{st} during the two growing seasons of 2013-2014 and 2014-2015.

1.2. Preparing of rice straw bales

Compacted rice straw bales (30 cm height x 45 cm width x 100 cm length) obtained from commercial supplier, were sterilized in boiling water and then were arranged to form ridge with two rows on each ridge in greenhouse for sweet pepper cultivation. Drip irrigation lines were extended on top of the rice straw bales with two drip lines on each row. The straw bales were first irrigated for six hours for washing out soil particles, then water irrigated daily for three weeks before transplanting to prevent reduction of its volume during growing season.

1.3. Transplants culture

Seedlings of sweet pepper which have three or four true leaves (45 days old) were transplanted into the greenhouses at a private farm at El-Salheya El-Gedida City, Ismailia Governorate, Egypt, in August 15^{th} during the two growth seasons in sandy soil and rice straw bales. The physical and chemical analysis of soil and water are presented in **Table 1 (A & B)**. The seedlings were transplanted on two side of ridge at 40 cm apart, the distances between seedling were 40 cm apart in both of rice straw bales and sandy soil. The plants were watered by the drip irrigation system until the end of the season.

Table 1.A. Chemical analysis of soil and water

	pH	EC	TDS	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}
Soil	7.5	4.080 ds/m	2659 mg/l	16.15 meq/l	9.54 meq/l	11.31 meq/l	3.06 meq/l	11.36 meq/l	1.20 meq/l	29.12 meq/l
Water	8.6	1410 µs/cm	697 mg/l	1.34 mg/l	0.77 mg/l	8.91 mg/l	0.51 mg/l	5.68 mg/l	2.69 mg/l	2.90 mg/l

Table 2.B. Physical properties of the experimental site soil

Particles size distribution (%)						Texture class
Very coarse sand	**Coarse sand**	**Medium sand**	**Fine sand**	**Very fine sand**	**Silt & Clay**	
2 - 1 mm	1 - 0.50 mm	0.50 - 0.25 mm	0.25 - 0.125 mm	0.125 - 0.064 mm	< 0.064 mm	
2.25	41.65	33.42	16.08	5.75	0.85	Sand

2. Experimental design and agricultural practices

2.1. Experimental design and tested factors

a) Deficit irrigation treatments were applied in 3 deficit levels (every 2, 3 and 4 days) in addition to daily irrigation as control. The irrigation applications started after 15 days from transplanting.

b) To maximize growth of sweet paper plants under deficit irrigation, application of potassium humate (K_2-HA) at 2 g/l, potassium silicate (K_2SiO_3) at 5 g/l, and seaweed extract (SWE) at 0.5 g/l in addition to tap water as control were used as soil drenching applications. Drenching applications were applied with 10-day intervals started after 15 days from transplanting. Potassium humate with the commercial name "Humic Total" (Technogreen Co. Egypt, and LEILI Agrochemistry Beijing, China) has the following properties (humic acid 80%- K_2O 12 % – water solubility: 98% soluble – pH: 8-9 – bulk density: 83 g/100ml). whereas, seaweed extract with the commercial name "Algaa 600" (Technogreen Co. Egypt, and LEILI Agrochemistry Beijing, China) has the following properties (organic matter 55 % - alginic acid 10 %- total nitrogen 0.6 % -phosphorus (P_2O_5) 5 % - potassium (K_2O) 20 % - Mg 0.06% - Ca 1.6% - Fe 0.3% - Cu 45ppm – S 1.5 % water solubility: 100% soluble – pH: 9-10).

c) Two types of growing media were used for this investigation; rice straw and sandy soil (control).

The experimental layout was split-split plot design with three replicates. Irrigation treatments were applied in the main plots, soil drenching applications were applied in the sub plots and the growing media were applied in the sub-sub plots. Total number of treatments is 32 (2 types of growing media X 4 drenching application X 4 irrigation levels). The experimental unit area (plot area) was 12 m^2.

2.2 Agricultural practices

Agricultural management, fertilization, disease and pest control programs were performed as recommended by the Egyptian Ministry of Agriculture and Land reclamation. The fertilization depended on the physiological status of sweet pepper plants during different stages of development.

3. Vegetative growth measurements

Plant samples were taken at random from each experimental plot at 90 days after transplanting (DAT), to record leaf area, shoot system fresh and dry weight.

- Leaf area (cm^2) was determined using leaf area meter machine model ADC Bioscientific Ltd., Japan. Samples were taken from fully expanded leaves (leaf number 4 from the top).
- Fresh weight (g) of shoot system (stem and leaves) was determined in g/plant.
- Dry weights of shoot system samples were placed in paper bags and dried in oven (70°C) until a constant dry weight was reached **(A.O.A.C., 2005)**.

4. Plant water status measurement

Determination of leaf relative water content (LRWC)

Leaf relative water content was determined according to the method of **(Schonfeld et al 1988)** in the full expanded fourth leaf from the top of the plant. Twenty leaf discs samples (10 mm in diameter) were taken with a cork borer from three plants per replicate and placed in a reweighed Petri dish to determine fresh weight (f.w), then discs were floated for 24 hours in distilled water inside a closed Petri dish until the discs became fully turgid. Discs samples were weighed periodically, after gently wiping the water from the leaf surface with a filter paper to determine turgid weight (t.w). Finally, the leaf discs were placed in a pre- heated oven at 80° C to a constant weight (almost 12 h) and weighed again to obtain dry weight (d.w). LRWC % was calculated using the values of (f.w), (t.w) and (d.w) according to the equation as follow:

$$\boldsymbol{LRWC}\,\% = \frac{\boldsymbol{f.w - d.w}}{\boldsymbol{t.w - d.w}} \times \mathbf{100}$$

5. Determination of minerals concentration

Samples of dried leaves (0.2 g) were wet digested in a mixture of H_2SO_4:H_2O_2 for chemical analysis of minerals P, K, and Ca **(A.O.A.C., 2005)**.

5.1. Nitrogen

Total nitrogen concentration was determined using the micro-Kjeldahl method as described by **Horneck and Miller (1998)**.

5.2. Phosphorus

Phosphorus concentration was determined using molybdovanadophosphoric acid colorimetric method according to **(Jackson, 1973).**

5.3. Potassium

The diluted digested sample (1 + 9 (v/v) with water) is nebulized into an air-propane flame, where it is vaporized; potassium compounds are atomized and the potassium atoms thus formed emit radiation of which the intensity is measured at a wavelength of 766.5 nm using flame emission spectrometer **(A.O.A.C., 2005)**..

5.4. Calcium

The diluted digested sample (1 + 9 (v/v) with water) is vaporized in an air-acetylene flame; calcium compounds are atomized and the CaOH molecules thus formed emit radiation of which the intensity is measured at a wavelength of 622 nm using flame emission spectrometer **(A.O.A.C., 2005).**

6. Statistical Analysis

Data of the two seasons were statistically analyzed using CoStat software (version 6.4, CoHort Software, USA) according to the method described by (**Gomez and Gomez (1984)**. Split-split plot analysis of variance (ANOVA) were used to test for significant differences among irrigation intervals, soil applications, types of cultivation media and their interactions at $P < 0.05$, followed by Tukey's HSD test.

RESULTS AND DISCUSSION

1. Growth parameters

Data presented in **Tables (2 - 4)** reveal the effect of growing media (sandy soil and compacted rice straw bales) and drenching applications of potassium humate (K_2-HA), potassium silicate (K_2SiO_3) and seaweed extract (SWE) on some growth parameters of sweet pepper plants grown under deficit irrigation; every 2 (I_2), 3 (I_3) and 4 (I_4) days in addition to daily irrigation (I_1) as control.

Mean values of irrigation treatments demonstrate significant increase in shoot fresh weight by I_2 followed by I_3 then I_4 compared to I_1in the two seasons of 2013/2014and 2014/2015. Significant increase in shoot dry weight was obtained by I_3 followed by I_2 then I_4 comparing to I_1, but there were no significant differences between I_4 and I_1 in the first season. An increase in leaf area was obtained by I_3 followed by I_2 then I_4 comparing to I_1, but there were no significant differences between I_2& I_3 and I_1& I_4 in the first season.

These results are in agreement with **Ezzo et al (2010),** they revealed that moderate and medium irrigation regimes were able to compete high irrigation levels regarding sweet pepper vegetative growth traits; total fresh and dry weights.

Mean values of drenching applications show significant increase in the growth parameters; shoot fresh and dry weights, and leaf area by all applications in the two seasons comparing to untreated control and the best results were due to K_2-HA followed by SWE then K_2SiO_3.

These results confirm with the findings of **Abou El-Nasr & Ibrahim (2011) and Awwad (2015)** who mentioned that application ofK_2-HA markedly increased vegetative growth of carrot and maize plants respectively**. Refaiy et al (2016)** revealed that K_2-HA significantly increased vegetative growth of Grandnaine banana plantlets. **Zhang and Schmidt (1997**) stated that seaweed products exhibit growth-stimulating activities. **Kowalski et al (1999)** described the positive impact of SWE on potato plant growth since they significantly affected shoot growth. Several workers proved that SWE contain a variety of plant hormones including cytokinins, auxins, gibberellic acid and salicylic acid determined indirectly by bioassays reviewed by **(Khan et al 2009 and Craigie, 2011**). Silicon application on *Tagetuspatula* L. significantly increased fresh and dry weights of plants **(Sivanesan et al 2010)**. Also, Si application to sorghum led to increase in leaf area index, specific leaf weight, chlorophyll content, root and leaf dry weights **(Ahmed et al 2011).**

Plants were grown on rice straw (RS) showed significant reduction in growth parameter values comparing to sandy soil (SS). These results are not consistent with the results of **Abdet-Sattar et al (2008) and El-Sayed et al (2015),** they stated that using rice straw as growing medium increased vegetative growth of strawberry and sweet pepper comparing with using natural soil or sandy soil respectively. However, it was tended in the present study to apply the same fertilization program to rice straw and sandy soil, while, **Abdet-Sattar et al (2008)** for instance used extra fertilization during preparing rice straw bales and this may explain the positive effect of rice straw on growth, whereas, they applied dissolved ammonium and potassium sulphate and phosphoric acid 85% fertilizers daily through the irrigation system, 10–12 days before planting, for rice straw fermentation.

Concerning interaction between treatments, plants irrigated every 2 days, grown on sandy soil and drenched with K_2-HA (I_2+ K_2-HA+ SS) showed the highest significant values of shoot fresh weight (493.00, 494.67g), shoot dry weight (49.67, 50.67g) and leaf area (121.94, 123.15 cm^2) comparing to control plants applied with I_1+ Control + SS which recoded shoot fresh weight (199.67, 201.33 g), shoot dry weight (40.67, 42.00 g) and leaf area (90.76, 91.98 cm^2) in the two seasons respectively. Marked increase in growth parameters was also recorded by I_2+SWE + SS, I_1 + K_2-HA+ SS, I_2 + K_2SiO_3+ SS, I_1+SWE + SS and I_3 + K_2-HA+ SS.

Meanwhile, plants were grown on RS showed significant increase in growth parameters but less than those were grown on SS. The best results of shoot fresh weight were achieved by I_3 + K_2-HA+ RS (376.00, 414.00 g) followed by I_3 + SWE+ RS (365.33, 383.00 g) or I_4 + K_2-HA+ RS (347.33, 399.00 g) in the two seasons respectively comparing to plants applied with I_1+ Control + SS (199.67, 201.33 g).

The previous results elucidate the stimulating effect of K_2-HA on growth parameters of plants were grown on SS under irrigation I_2 &I_3. Meanwhile, SWE and K_2SiO_3 enhanced growth of plants grown on SS under irrigation I_2.

The role of K_2-HA as bio-stimulant in stimulating plant growth and reducing the effect of abiotic stress has been established by **Rafat et al (2012)** and **Awwad (2015)** on *Zea. mays* L. under water deficiency stress and by **Refaiy et al (2016)** on

Grandnaine banana plantlets under salt stress. The role of seaweed extract on improving growth under drought stress has been mentioned by **Spann and Little (2011)** on orange trees and by **Xu and Leskovar (2015)** on fresh and dry weights of spinach (*Spinacia oleracea* L.) plants.

Liu et al (2009) mentioned that silicon additions increased forage biomass (increased shoot development and plant height) under moderate water stress and increased shoot development of alfalfa (*Medicago sativa*) under light water stress. Potassium humate and SWE stimulated growth parameters of plants grown on RS under higher levels of water deficit I_3& I_4. These results obviously demonstrate the positive effect of RS on keeping water under water deficiency condition. **El-Sayed et al (2015)** demonstrated that rice straw as a growing substrate can improve the production of pepper plants under greenhouse conditions with saving 35-38% of irrigation water.

2. Leaf relative water content

Mean values of irrigation, data in Table (5) show that the highest values of leaf relative water content (LRWC) were recorded by I_3 followed by I_4 then I_2 and I_1.

Drenching applications showed significant increase in LRWC values by all applications in the two seasons comparing to untreated control and the best results were due to K_2-HA followed by SWE then K_2SiO_3.

Plants were grown on RS showed significant increase in leaf relative water content (LRWC); 74.72, 76.00 % comparing to plants were grown on SS; 58.88, 60.14% in the two seasons respectively.

Application of I_3 + K_2-HA+ RS resulted in the highest significant values of LRWC (89.80, 91.36 91.36%) while plants were grown on SS and received the same treatments I_3 + K_2-HA+ SS recoded (61.75, 63.82%) in the two seasons respectively. However, plants were grown on RS surpassed plants grown on SS in LRWC. High values of LRWC were recorded by I_3 + SWE+ RS (82.54, 84.26%) and I_4 + K_2-HA+ RS(89.13, 90.84%) comparing to I_1+ Control + SS (56.77, 58.37%).

The superiority of rice over LRWC confirm the finding of **El-Sayed et al (2015)** that straw culture may be recommended for the sweet pepper production and reducing water consumption under greenhouse conditions. The increase of LRWC in plants grown on RS under I_3 &I_4 and were applied withK_2-HA is referred to the impact of K_2-HA on alleviating water stress influences as mentioned by **Rafat et al (2012)** and **Awwad (2015)**.

3. Nutrient elements

Tabulated data in **Tables (6-9)** show the effect of deficit irrigation, drenching applications, growing media and their interactions on some macronutrients; N, P, K and Ca. Plants were grown on SS showed significant increase in N, K and P concentrations. Meanwhile, there was no significant differences in Ca concentrations between both growing media.

Application of K_2-HA gave the highest concentrations of N, P and Ca followed by SWE then K_2SiO_3. The highest concentration of K was obtained by K_2SiO_3 followed by K_2-HA then SWE.

Data in **Table (6)** show that I_2+ K_2-HA+ SS gave the highest significant values of N concentration followed by I_2+SWE+SS then I_2 + K_2SiO_3+ SS and I_1+ K_2-HA+ SS in both seasons. Significant increases of N concentration were also obtained by I_3+ K_2-HA+ RS, I_3+ SWE+RS and I_4+ K_2-HA+ RS in the two seasons comparing with control plants I_1+ Control + SS.

Data in **Table (7)** reveal that the highest significant values of P concentration were obtained by I_2+ K_2-HA+ SS followed by I_2+SWE+SS and I_1+ K_2-HA+ SS thenI_3+ K_2-HA+ RS. There were no significant differences between I_3+ K_2-HA+ RS and I_2+ SWE+ SS in both seasons. Application of I_3+SWE (or K_2SiO_3) +RS and I_4+ K_2-HA+ RS showed significant increase in P concentrations comparing with control plants I_1+ Control + SS.

The highest values of K concentration **(Table 8)** in the two seasons were obtained by I_4+ K_2SiO_3+ SS followed by I_4+SWE+ SS then I_4+ K_2-HA+ SS. Plants were grown on RS underI_2, I_3 or I_4 in combination with K_2SiO_3 gave significant increase in K concentrations comparing with control plants I_1+ Control + SS.

The highest values of Ca concentration **(Table 9)** were obtained by I_2+ K_2-HA+ SS followed by I_2+SWE+SS and I_3+ K_2-HA+ RS then I_2 + K_2SiO_3+ SS, I_1+ K_2-HA+ SS and I_3+ SWE + RS in the two seasons. Also, significant increase in Ca concentration were induced by I_2+ K_2-HA +RS, I_3+ control (or K_2SiO_3) + RS and I_4 + RS plus all drenching applications.

Generally, all drenching applications increased the concentration of the macronutrients under study. Plants were grown on rice straw under I_3 irrigation and applied with K_2-HA or SWE showed significant increase in N, P and Ca concentrations, while, under I_4 irrigation an increase in N and P concentrations was obtained by K_2-HA. While, K_2SiO_3 surpassed other treatments with K concentration under I_3 &I_4. These results confirm with the finding that humic substances enhance the uptake of K, Ca, magnesium Mg and P **(Chen and Aviad, 1990).** Potassium humate can be used as organic potash fertilizers. It supplies high levels of soluble in readily available forms. Combined with humic acid, potassium, can be rapidly absorbed and incorporated into plant whether via soil or foliar application methods. Enhancement of plant growth using K_2-HA had been reported to be due to increasing nutrients uptake such as N, Ca, P, K, Mg, Fe, Zn and Cu **(David et al 1994 and Adani et al 1998). Mancuso et al (2006) and Rathore et al (2009)** on soybean observed increases in yield as well as N, P and K concentrations with application of SWE. **Masny et al (2004)** and **Attememe (2009)** mentioned to the presence of macronutrients in SWE responsible for the improvement of fruit and shoot characters induced by SWE application. **Parida and Das (2005)** mentioned that selective accumulation of ions is one of the strategies plants develop to cope with abiotic stress and this may explain why the highest concentrations of k were observed under the highest level of irrigation deficit I_4 by K_2SiO_3 followed by other drenching applications of plants were grown on SS. With regard that, plants were grown under I_4 on SS exposed to higher water stress comparing to those grown on RS under the same irrigation level. The positive impact of K_2SiO_3 on k concentration is partially attributed to being potash fertilizers.

It could be concluded from the present study that rice straw could alleviate the negative effect of low water supply and applications of K_2-HA and SWE are recommended for enhancing sweet paper growth and nutrient elements uptake under water deficit conditions.

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