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RESEARCH ARTICLE

Effect of Soil Application of Humic Acid and Hydrogel on Morpho-Physiological and Biochemical Attributes of Potato (*Solanum tuberosum* L.)

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ABSTRACT

Effects of Humic acid and hydrogel with and without recommended dose of NPK in eight different treatments and four replications were studied. Humic acid revealed better results as compared to hydrogel for number of leaves, and potassium contents plant^{-1} whereas in all the other studied growth and yield parameters hydrogel performance was good. Overall results revealed that both humic acid and hydrogel improved nutrient's uptake efficiency as well as reduce environmental pollution in agriculture. The treatment T_7 (80 mg Hydrogel treatment (two doses) + NPK) exhibited highest tuber's yield while T_0 (control) reported minimum yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a starchy, tuberous crop belongs to the Solanaceae family (also known as the Nightshades). It is the world's fourth largest food crop, following rice, wheat and maize. It is high yielding, having high nutritive value and gives high returns to farmers. Its area and production in Pakistan is 185.1(000 ha) and 4104.4 (000 tons), respectively, which increased by 16.5 % and 17.5 % during, 2011-12 (Anonymous, 2012). Potato is a shallow rooted crop. It requires high organic matter in the soil and heavy feeding. It is sensitive to the higher level of irrigation and the fertilizers, more preferably for the quality and high tuber yield (Peralta and Stockle, 2001). Soil health is a crucial factor for obtaining a higher yield in vegetable crops. In Pakistan, the soils are very poor in organic matter (< 1%) due to high temperature for most of the time of the year. It results in poor soil health and structure and subsequently, reduces microbial activity along-with plant growth and yield. So, there is a need to use traditional as well as non-traditional composts, as an effective mean for improving soil structure, fertility, moisture holding capacity and cation exchange capacity of soil. They also help in increasing microbial populations and activity (Marinari et al., 2000). Therefore, in order to feed increasing population, it is imperative to improve crop productivity with least effect on environment. This could only be achieved by an integration of conventional with non-conventional approaches (Humic acid, hydrogel etc.). Humic acid affects chemical and biological properties of the soil as well as morpho-physiological processes of a plant (Ohta et al., 2004). Humic acid is beneficial to shoot and root growth by playing a role in nutrient's uptake in vegetable crops (Dursun et al., 2002; Cimrin and Yilmaz, 2005). Hassanpanah and Khodadadi (2009) treated potato plants with potassium humate and reported maximum seed germination percentage, number of tubers, average weight of tubers per plant and tuber yield. Mawgoud et al. (2007) applied Grow-Plex SP^{TM} (a water soluble fertilizer with humic acid) and testified increased number of leaves, fresh and dry weight along-with increment in endogenous hormonal level and improved production and quality in tomato crop. Also, humic substances have a direct action on plant growth by influencing metabolic processes such as nucleic acid synthesis, and ion uptakes, as a growth regulator to regulate hormone levels (Serenella et al., 2002). In particular, the photosynthesis efficiency and chlorophyll content were significantly increased in humus-treated plants.

Water-retentive chemicals are polymers (e.g., hydrogel) which become gel in contact with water. It leads to its use as soil stabilizers, water purifiers, juice clarifiers, animal feed thickeners, and in the processing of oil, pulp and paper, and fruits and vegetables. Hydrogel does not dissolve, but forms a gel when water is added. As they dry, water is slowly released to the soil. Bharadwaj et al. (2007) reported polymers which retained water (40 and 140 kg kg^{-1}) when mixed with sand. They increased compressive strength of soil particles and developed resistance to wind erosion. They are easily biodegradable and therefore, safe to apply in the field (Yang et al., 2008). Furthermore, pure gel polymers, especially at higher fertilizer rate, improved total and marketable tuber yield (Eiasu et al., 2007). Hayat and Ali (2004) reported 30% to 850% increase in moisture contents and 17% elevation in saturation percentage. They also observed 8% reduction in particle density along-with 4% to 80% reduction in bulk density in the soil treated with polymer as compared to non-treated soil. According to another study, polyacrylamides and other soil-wetting polymers, incorporated into sandy potato fields, increased 102% water retention in the soil around the root zone and subsequently**,** 25% increase in tuber yield (Watt and Peake, 2001). It has also been noted that gel-polymers stimulate seedling growth (Al-Harbi et al., 1999). Magalhaes et al. (1987) found higher retention of NH_4, K, Ca, Mg, Zn, and Fe in an oxisol treated with gel-polymers as compared to untreated soil. In addition, a higher shoot growth as well as N, K, and Fe uptake in radish was found in soils amended with gel-polymers.

The present experiment was designed to monitor the effects of humic acid and hydrogel on growth and yield performance of potato (*Solanum tuberosum* L.) var. Sante.

MATERIALS AND METHODS

The study was carried out at Vegetable Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan during autumn season, 2009-10. Soil samples were collected from experimental field, air-dried, thoroughly mixed and passed through 2-mm sieve. Physical and chemical characteristics and macro nutritional status of the soil are shown in Table-1. Tubers were planted on ridges, having 15 cm plant to plant and 75 cm row to row distance. Humic acid and hydrogel were applied directly into soil along with NPK.

There were total eight different treatments of Humic acid and Hydrogel that were randomized in selected plots: T_0 (Control), T_1 (Recommended dose of NPK (250:150:150 ha^{-1}), T_2 (120 ml of 8% Humic acid / treatment in three doses), T_3 (120 mg Hydrogel/ treatment in three doses), T_4 (80 ml of 8% Humic acid/ treatment (two doses) + NPK), T_5 (120 ml of 8% Humic acid / treatment (three doses) + NPK), T_6 (40 mg Hydrogel / treatment (one dose) + `NPK), T_7 (80 mg Hydrogel / treatment (two doses) + NPK). Design of Experiment was RCBD which was replicated four times. At the stage of 60 day old crop, total emergence (%), Number of shoots/plant, Number of leaves/plant, Height of the plant (cm), Foliage fresh weight/plant (g), Foliage dry weight/plant (g), Tuber dry weight/plant (g), Tuber yield/ha (tones), chlorophyll and protein contents (µg) were sampled from five plants per treatment per replication . Similarly, Leaf samples were used for the estimation of N, P and K. N (mg L^{-1}) contents was studied according to Chapman and Parker method (1961). Whereas P (mg L^{-1}) and K (mg L^{-1}) were estimated according to the method described by Yoshida et al. (1976). Total chlorophyll contents (mg g^{-1}) were determined with the help of chlorophyll meter. Total protein contents were estimated by a formula (Nitrogen calculated x 6.25). The collected data was subjected to ANOVA and treatment means were compared through LSD test at 5% level of probability (Steel et al., 1997).

RESULTS AND DISCUSSION

Growth parameters

Data regarding growth attributes is given in Table 2. T_0 showed maximum mean emergence percentage (98.75%) as compared to T_3 which represented minimum emergence percentage (93.75%). It can be concluded that days to emergence depend upon internal vigor of the tubers and microclimate in the vicinity of the crop. It is depicted from the data that T_5 displayed maximum number of leaves (231.33) followed by T_7 (227.83) that were 52.65 and 51.94% higher than T_0 which reported least number of leaves (112). Mawgoud et al. (2007) also reported a significant increase in the number of leaves with the application of water soluble fertilizer along with humic acid. Humic compounds subsequently enhanced photosynthetic rate (Zhang et al., 2006). Moreover, Maximum number of shoots exhibited by T_6 (3.42) that were 64.7 % higher than T_0 which disclosed minimum number of shoots (2.66). But number of shoots of T_6 treatment were less vigorous as compared to T_4 (3.37), T_7 (3.27) and T_2 (2.95). Although number of shoots produced by T_4, T_7 and T_2 treatments were less in numbers but more vigorous and strong, more in height and had additional number of leaves as compared to others. Furthermore, both humic acid as well as hydrogel showed decreasing trend with increase in dose regarding number of shoots. It was concluded from experiment that T_7 pointed out maximum plant height (50.93 cm) that was 27.68%

Table 1: Physical and chemical properties and Macro nutritional status of soil

Soil analysis	Soil Depth	
	0-6 (inches)	6-12 (inches)
Texture	Loamy	Loamy
pH	9.30	8.10
EC (ds m^{-1})	0.42	0.37
Exchangeable Sodium (m mole / 100g)	0.0	0.70
Organic matter (%)	0.51	0.54
Nitrogen mg (mg L^{-1})	0.032	Weak
Phosphorous (mg L^{-1})	4	Too weak

higher than T_0 which showed minimum plant height (36.83 cm). Fresh foliage weight plant^{-1} (142.75 g) was maximum demonstrated by T_7 that was 42.46% higher than T_0 which unveiled lowest fresh foliage weight plant^{-1} (82.13 g). Positive effects of humic acid on shoot and root growth of plants were observed by Dursun et al. (2002). Furthermore, these results are also in accordance with Ezzat et al. (2011) who reported significant increase in plant height and relative growth rate in potato leaves due to application of veterra hydrogel. Koupai et al. (2008) observed maximum effect of polymer addition on the height of *Ligusrum ovalifolium* (an ornamental plant).

Moreover, highest foliage dry weight plant^{-1} (31.875 g) was recorded in T_7 that was 49.4% higher than T_0 that manifested lowest foliage dry weight plant^{-1} (18.85 g). Also, both (humic acid and hydrogel) exhibited increasing trend with rise in dose. Humic acid improves shoot and root growth along with nutrient uptakes in vegetable crops (Dursun et al., 2002; Cimrin and Yilmaz, 2005). Furthermore, T_7 displayed maximum dry weight of the tubers plant^{-1} (4.85 g) that was 21.35 % higher than T_0 which publicized minimum dry weight of tubers plant^{-1} (3.5 g). Likewise, Ghasemi and Khushkhui (2008) reported that hydrophilic gels (0.8%) had positive and significant effect on average number and area of leaves (42%), shoot fresh and dry weight, shoot number (24%) and plant height (45%) as compared to control. Similarly, Syvertsen and Dunlop (2004) did experiment on citrus seedlings grown in well-watered sand soil amended with hydrogel and reported increase in growth.

Tuber's yield ha^{-1} (42.54 tones ha^{-1}) displayed an increasing trend with increase in hydrogel (T_7) followed by T_5 (40.16 tones ha^{-1}) that was 55.76 and 53.14%, respectively, higher than T_0 which expressed minimum average yield (18.82 tones ha^{-1}). Probably, increase in yield was due to an increase in vegetative growth traits, chlorophyll content and tuber macro and micronutrients. This yield enhancement as a result of hydrogel application is in agreement with the results obtained by Eiasu et al. (2007) who found that the pure gel polymer, especially at higher fertilizer rate, improved total and marketable tuber yield. Yield performance of humic acid was not satisfactory as compared to hydrogel. Additionally, these results are in harmony to those obtained by Shock et al., (2009). They found that application of Stockosorb® (soil conditioner) produced higher total and marketable yield of U.S. No. 1 tubers of potatoes. Watt and Peake, (2001) stated 25% increase in tuber yield.

Physiological and biochemical attributes

Data regarding Physiological and Biochemical parameters is presented in Table # 3. As far as average nitrogen contents are concerned T_7 (0.555 mg l^{-1}, 15.52 % > T_0) followed by T_5 (0.551 mg) portrayed an increasing trend with rise in dose. Syvertsen and Dunlop (2004) used hydrogel and reported higher nitrogen uptake and reduction in loss of nitrogen by leaching from soils. In case of phosphorous contents plant^{-1} T_7 showed best results (0.298 mg l^{-1}) followed by T_5 (0.296 mg l^{-1}) as compared to T_0 (0.268 mg l^{-1}) that demonstrated minimum outcome. So, performance of Humic acid and hydrogel expressed increasing trend with rise in dose regarding P contents. It is obvious from facts that T_5 presented maximum results for potassium contents plant^{-1} (31.287 mg l^{-1}) followed by T_7 (30.087 mg l^{-1}) among all the treatments applied that were 22.14% and 19.03% higher than T_0 which showed minimum average potassium contents plant^{-1} (24.36 mg l^{-1}). Moreover, K^+ contents increased consistently with increased in humic acid and hydrogel. These results are favored by Bredenkamp (2000) who reported that Hydrogel improves macro and micro nutrient uptake especially nitrogen, potassium and phosphorus as Aqua-Soil TM retained up to 400% more nitrogen and 300% more potassium than standard quick and slow release fertilizers. Further, Cimrin and Yilmaz (2005) testified increased nutrient uptake including K^+ in vegetable crops with humic acid application.

Rgarding total chlorophyll contents plant^{-1}, T_7 (45.38 mg g^{-1}, 30.2% > T_0) and T_5 (43.94 mg g^{-1}, 27.92% > T_0), respectively, revealed better effects while, T_0 (31.67 mg g^{-1}) showed minimum result. It was also observed from experiment (Table 3) that humic acid exhibited decreasing trend with increase in humic acid (T_5) level as compared to hydrogel that expressed increasing drift with increase in hydrogel dose. In case of protein contents T_7 (3.63 µg) and T_5 (3.48 µg) presented maximum and significant results for protein contents plant^{-1} among all the treatments applied that was 15.71% higher than T_1 that depicted minimum protein contents plant^{-1} (3.48 µg). Protein contents plant^{-1} increased consistently with increasing amount of hydrogel (T_7) as well as humic acid (T_5). Selim et al. (2012) did research on potato and reported that leaf chlorophyll and protein contents were positively influenced under the effect of humic acid. These results are in accordance with Ezzat et al. (2011) who reported significant increase in total chlorophyll contents in

Table: 2 Effect of humic acid and hydrogel on morphological attributes of potato.

Treatments	Total Emergence (%)	No. of Shoots Plant^{-1}	No. of Leaves Plant^{-1}	Plant Height (cm)	Foliage Fresh wt. plant^{-1} (g)	Foliage Dry wt. Plant^{-1} (g)	Tuber's Yield (tones/ha^{-1})	Tuber's Dry Wt. (g) (15gram fresh tubers)
T_0	98.5	2.66	112.00	36.83	82.13	18.85	18.82	3.53
T_1	97.5	3.35	186.30	45.72	128.57	27.55	35.32	4.12
T_2	97.5	2.95	154.13	37.57	94.71	20.35	19.89	3.84
T_3	93.75	3.25	173.00	39.16	87.87	19.93	21.85	3.96
T_4	97.5	3.37	210.00	43.10	131.84	28.25	36.86	4.29
T_5	93.75	3.25	231.33	46.05	139.65	30.92	40.16	4.57
T_6	95.00	3.42	192.63	44.92	133.0	29.21	37.16	4.45
T_7	95.5	3.27	227.83	50.93	142.75	31.87	42.54	4.85

T_0 (Control), T_1 (Recommended dose of NPK (250:150:150 ha^{-1}), T_2 (120 ml of 8% Humic acid / treatment in three doses), T_3 (120 mg Hydrogel / treatment in three doses), T_4 (80 ml of 8% Humic acid / treatment (two doses) + NPK), T_5 (120 ml of 8% Humic acid / treatment (three doses) + NPK), T_6 (40 mg Hydrogel / treatment (one dose) + `NPK), T_7 (80 mg Hydrogel / treatment (two doses) + NPK).

Table 3: Effect of humic acid and hydrogel on Physiological and Biochemical parameters of potato

Treatments	Nitrogen estimation (mg l^{-1})	Phosphorous evaluation (mg l^{-1})	Potassium inference (mg l^{-1})	Chlorophyll contents (mg g^{-1})	Protein contents (µg)
T_0	0.491	0.268	24.36	31.67	3.06
T_1	0.515	0.291	27.507	43.535	3.21
T_2	0.50	0.271	26.89	33.821	3.125
T_3	0.499	0.286	26.92	35.635	3.12
T_4	0.549	0.292	28.857	44.38	3.437
T_5	0.551	0.296	31.287	42.44	3.44
T_6	0.544	0.293	29.705	41.635	3.40
T_7	0.555	0.298	30.085	45.94	3.468

T_0 (Control), T_1 (Recommended dose of NPK (250:150:150 ha^{-1}), T_2 (120 ml of 8% Humic acid / treatment in three doses), T_3 (120 mg Hydrogel / treatment in three doses), T_4 (80 ml of 8% Humic acid / treatment (two doses) + NPK), T_5 (120 ml of 8% Humic acid / treatment (three doses) + NPK), T_6 (40 mg Hydrogel / treatment (one dose) + `NPK), T_7 (80 mg Hydrogel / treatment (two doses) + NPK).

potato leaves due to application of veterra hydrogel. El-Sayed et al. (1990) reported that generally chloroplast pigments (chlorophyll a, chlorophyll b, and carotenoids), photosynthetic activity and protein contents were increased with polymer incorporation compared with control in vegetables (i.e., tomato, lettuce and cucumber).

In a nutshell, it can be concluded that the effect of applied humic acid and hydrogel with recommended dose of NPK on plant morpho-physiological, biochemical and yield attributes, were persistent. Furthermore, effects of addition of humic acid and hydrogel reinforced with full recommended dose of NPK produced a significant increase in potato yield. So, their use offers great potential as a low cost natural fertilizer with sustainable yield. Additionally, they will not only be helpful in optimizing the yield but also ameliorating the stress as well as controlling erosion.

REFERENCES

El-Sayed H, RC Kirkwood and NB Graham, 1990. The effect of a hydrogel polymer on the growth of certain horticultural crops under saline conditions. Journal of Experimental Botany, 42: 891-899.

Ezzat AES, AA El-Awady and HMI Ahmed, 2011. Improving Nitrogen Utilization Efficiency by Potato (*Solanum tuberosum* L.). Nature and Science, 9: 34-42.

Al-Harbi AR, AM Al-Omran, AA Shalaby and MI Choudhary, 1999. Efficacy of a hydrophilic polymer declines with time in greenhouse experiments. Horticultural Science, 34: 223-224.

Anonymous, 2012. Economic Survey of Pakistan. Government of Pakistan, Finance Division. Economic Adviser Wing, Islamabad, pp: 21.

Bredenkamp G, 2000. Improved retention of macronutrients/reduced leaching. University of Pretoria. http://www.silvix.co.za/aquasoil. htm.

Bharadwaj AK, I Shainberg, D Goldstein, DN Warrington and GJ Levy, 2007. Water retention and hydraulic conductivity of cross-linked polyacrylamides in sandy soils. Soil Science Society of America Journal, 71: 406-412.

Chapman, HD and F Parker, 1961. Determination of NPK. Method of analysis for soil, plant and water. Division of Agriculture, University of California, pp: 150-79.

Cimrin KM and I Yilmaz, 2005. Humic acid applications to lettuce do not improve yield but do improve phosphorus availability. Soil and Plant Science, 55: 58-63.

Dursun A, I Guvenc and M Turan, 2002. Effects of different levels of humic acid on seedling growth and macro and micronutrient contents of tomato and eggplant. Acta Agrobotanica, 56: 81-88.

Eiasu B, KP Soundy and PS Hammes, 2007. Potato yield and soil physical properties as affected by gel-polymer soil amendments and irrigation management. MSc Thesis. University of Pretoria, South Africa.

Ghasemi M and M Khushkhui, 2008. Effects of super absorbent polymer on irrigation interval and growth and development of Chrysanthemum (Dendranthema×grandiflorum Kitam.). Journal of Science and Technology, 8: 65-82.

Hassanpanah D and M Khodadadi, 2009. Evaluation of potassium humate effects on germination, yield and yield components of HPS-II/67 hybrid true potato seeds under in vitro and in vivo conditions. American Journal of Plant Physiology, 4: 52-57.

Hayat R and S Ali, 2004. Water Absorption by Synthetic Polymer (Aquasorb) and its effect on soil properties and tomato yield. International Journal of Agriculture and Biology, 6: 998-1002.

Koupai JA, SS Eslamian and JA Kazemi, 2008. Enhancing the available water content in unsaturated soil zone using hydrogel to improve plant growth indices. Ecohydrology and Hydrobiology, 1: 67-75.

Magalhaes GEW, FC Rodrigues, FLIM Silva and ANF Rocha, 1987. Plant growth and nutrient uptake in hydrophilic gel treated soil. Communications in Soil Science and Plant Analysis, 18: 1469-1478.

Marinari S, G Masciandaro, B Ceccanti and S Grero, 2000. Influence of organic and mineral fertilizers on soil biology and physical properties. Bioresource Technology, 72: 9-17.

Mawgoud A, M El-Greadly, YI Helmy and SM Singer, 2007. Response of Tomato plants to different rates of humic acid based fertilizer and NPK fertilization. Journal of Applied Science Research, 2: 169-174.

Ohta K, S Morishita, K Suda, N Kobayashi and T Hosoki, 2004. Effects of chitosan soil mixture treatment in the seedling stage on the growth and flowering of several ornamental plants. Journal of Japanese Society of Horticultural Science, 73: 66-68.

Peralta JM and CO Stockle, 2001. Dynamics of nitrate leaching under irrigated potato rotation in Washington State: a long-term simulation study. Agriculture, Ecosystem and Environment, 88: 23-34.

Selim EM, IS Shaymaa, FA Faiz and AS El-Neklawy, 2012. Interactive Effects of Humic Acid and Water Stress on Chlorophyll and Mineral Nutrient Contents of Potato Plants. Journal of Applied Sciences Research, 8: 531-537.

Serenella, ND Pizzeghelloa, A Muscolob and A Vianello, 2002. Physiological effects of humic substances on higher plants. Soil Biology and Biochemistry, 34: 1527-1536.

Shock CC, E Feibert and LD Saunders, 2009. Evaluation of stockosorb® as a soil conditioner for potato production. Malheur Experimental Station, Oregon State University Ontario, USA, pp: 4.

Steel RGD, JH Torrie and DA Dicky, 1997. Principles and Procedures of Statistics: A Biometrical Approach, 3rd ed. McGraw Hill Book Company, Singapore.

Syvertsen JP and JM Dunlop, 2004. Hydrophilic gel amendments to sand soil can increase growth and nitrogen uptake efficiency of citrus seedlings. Horticultural Science, 39: 267-271.

Watt S and R Peake, 2001. Potato production on sandy soil in Australia: PIRSA rural solutions. (http://www.sardi.sa.gov.au/pages/horticulture/pathology/ hortpnpotsand.htm: sectID=323 and tempID=152).

Yang J, F Wang and T Tan, 2008. Synthesis and characterization of a novel soil stabilizer based on biodegradable poly (aspartic acid) hydrogel. Chemical Engineering, 25: 1076-1081.

Yoshida AS, DO Fornno, JL Cock and KA Gomez. 1976. Laboratory manual for physiological studies on rice. IRRI, Manila, Philippines.

Zhang J, R Liu, A Li and A Wang, 2006. Preparation, Swelling Behaviors, and Slow-Release Properties of a Poly (acrylic acid-*co*-acrylamide) / Sodium Humate Superabsorbent Composite. Industrial and Engineering Chemistry Research, 45: 48-54.