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Organic sources use of amino acids based biostimulants and irrigation schedule on yield: Water use efficiency relationship on potato tuber

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Abstract
The field experiment was conducted alluvial soil of Indo-Gangatic plain at the Institute Agricultural Research Farm, Banaras Hindu University, Varanasi, Uttar Pradesh, India. The field experiment of potato crop was laid out in a split-plot design with three irrigation schedules (I_1, I_2 & I_3) in main-plots and sub-plot spray three types amino acid based biostimulants (A_0, A_1, A_2 & A_3) at three application schedule of amino acid with three replications. The trail of potato crop seeds was planted *rabi* season and the recommended dose of fertilizers for the crop was 150:100:120NPK kg ha^{-1}. The maximum yield of potato tuber was recorded both years of experiment were observed in four irrigation schedule and plant based amino acids (I_2A_2). The interaction effect of maximum WUE was observed in I_1A_3 treatment combination in the year 2014-15 and I_2A_2 treatment combination in the year 2015-16. The soil properties in the field experimental site of soil reaction were noticed mildly alkaline and sandy loam soil.

Keywords: Amino acids based biostimulants, irrigation schedule and potato yield- water use efficiency (WUE).

Introduction

Potato (*Solanum tuberosum* L.) crop is a belonging to the Solanaceae family and very important place in world agriculture, with a production potential of about 327 million t harvested and 18.6 million ha planted area (FAO, 2006) [12]. Potato requires cool temperature and sandy loam soil with plenty of humus and moisture (Alim, 1974) [2]. The potato is a crop which has always been the 'poor man's friend'. Potato is an important food crop in the world (Herklots, 1972) [13] and possesses he characteristics of high yield, low cost and a nutritious and palatable food. For vegetable purposes it has become one of the most popular crops in this country. These are an economical food; they provide a source of low cost energy to the human diet are a rich source of starch, carbohydrates, protein, crude fiber, vitamins especially C and B_1 and minerals. They also contain a good amount of essential amino acids like leucine, tryptophane and isoleucine etc. Potatoes are used for several industrial purposes such as for the production of starch, glucose, destrine and alcohol. Potato starch (farina) is used in laundries and for sizing yarn in textile mills. As a food product itself, potatoes are converted into dried products such as 'potato chips', 'sliced' or 'shredded potatoes' and namkins. Potato as one of the world (Thompson and Kelly, 1972) [30] leading vegetable crops and cheapest source of carbohydrates and furnishes appreciable amount of vitamin as well as minerals.

Water is the key input in potato production and the problems of water management vary from region to region. The crop requires frequent irrigation for optimum growth. Quantitatively, transpiration and evaporation are the major components of water use by crop. Under irrigation, potato crop is mainly grown ridges and most common methods for potato are furrow and sprinkler. Thus, water supply and scheduling are important in terms of quality of potato tuber. Water requirement of potato is quite high (500-600 mm). The effects of different irrigation methods on yield and yield components of potato and water use of methods were investigated by (Yavuz *et al*., 2012) [33]. The effects of different irrigation methods which were used in this study were sprinkler, furrow and drip irrigation. The highest water use efficiency (WUE) and irrigation water use efficiency (IWUE) were obtained with drip irrigation plots while the lowest were obtained from sprinkler irrigation. To evaluate the effect of different irrigation methods and irrigation regimes on potato yield (Erdem *et al.,* 2006) [10] was grown under furrow and drip irrigation methods and three regimens: irrigation applied when 30, 50, or 70% of the available water was consumed. Water use efficiency values increased from 4.70 to 6.63 kg m^{-3} for furrow-irrigated treatments, and from 5.19 to 9.47 kg m^{-3} for drip-irrigated treatments. The WUE decreased with the increase of water use or irrigation frequency.

Growth of a potato plant occurs in several stages: sprout development, plant establishment, tuber initiation, tuber bulking and tuber maturation. Timing of these growth stages varies depending upon environmental factors, such as elevation and temperature, soil type, availability of moisture, cultivar selected and geographic action. Water stress (inadequate water) will lead to earlier tuber initiation of potato, whereas, excessive irrigation can also reduce tuber growth by restricting plant physiological activity and nutrient uptake and increasing disease susceptibility.

The amino acid based biostimulants group consists of peptides and/or free amino acids which can be obtained by chemical and /or enzymatic hydrolysis of an organic matrix from plant or animal origin and their composition can be highly variable (Maini, 2006) [17]. Several studies have found that the application, in small amounts, of products containing amino acids usually led to the improvement of plant metabolism, including nitrogen and carbon metabolism, and the resistance of plants to abiotic (e.g. drought, salt lorence etc.) and biotic stress (Maini, 2006 [17]; Kauffman *et al.,* 2007 [16]; Schiavon *et al*., 2008 [24]; Parad-ikovic´ *et al*., 2011) [20]. Amino acids are used as foliar spray to improve the growth, yield and quality of crops (Mazher *et al*., 2011 [18]; Takeuchi *et al*., 2008) [28]. Several researchers found positive impacts of amino acids as foliar spray under stress condition for example proline to wheat (Rajagopal and Sinha, 1980) [23],proline, alanine, serine, and asparagine to maize (Thakur and Rai,1985) [29] under osmotic stress and proline, phenylalanine to maize and board bean under salinity stress (Abd El-Samad *et al*., 2011) [1]. Several researchers found positive impacts of amino acids as foliar spray under stress condition for example proline to wheat (Rajagopal and Sinha, 1980) [23], proline, alanine, serine, and asparagine to maize (Thakur and Rai, 1985) [29] under osmotic stress and proline, phenylalanine to maize and board bean under salinity stress. As this biostimulant have enhanced the plant proline concentration and proline enzyme regulate plant stomata to improve WUE and decrease irrigation application schedule in potato crop through application of amino acid biostimulant in different growth stages of potato.

Materials and Methods

The field experiment was conducted for two consecutive years (2014-15 and 2015-16) to investigate at the Institute of Agricultural Research Farm, Banaras Hindu University, Varanasi, which is research farm situated at North – East plains Zone of the Eastern part of Uttar Pradesh at 25^0 18′ North Latitude 83^0 36′ East longitudes and at an altitude of 80.71 meters above mean sea level in the Gangatic plain of Eastern Uttar Pradesh. The district Varanasi having alluvial soil lies in semi arid region to sub humid belt of Northern India. The district Varanasi falls in a semi-arid to sub-humid climate and means annual precipitation is 1100 mm. The area occasionally experiences winter cyclonic rain during December to February. In term of percentage of total rainfall, about 84% is received from June to September (table, 1) 0.7% October to December, 6% from January to February and 9.3% from March to May as premonsoonic rain. The trial was laid out in a split-plot design with three irrigation schedules (I_1, I_2 & I_3) in main-plots and four amino acid based biostimulants (A_0, A_1, A_2 & A_3) in sub-plots with three replications. The variety of potato (E-3797) tuber seeds were planted *rabi* season 2014-15 and 2015-16, respectively.

Table 1: Monthly average meteorological during the cultivation period

	2014-15					Mean	2015-16					Mean
	November	December	January	February	March		November	December	January	February	March	
Rainfall (mm)	0.00	2.80	1.52	0.00	0.64	0.99	0.00	0.03	0.25	0.08	1.14	0.30
Maximum Temperature (^{0}C)	27.41	21.14	16.58	17.91	29.57	22.52	29.79	23.38	22.15	26.68	32.16	26.83
Minimum Temperature (^{0}C)	13.76	9.40	10.31	13.51	16.95	12.79	17.47	11.02	9.89	13.21	17.40	13.80
Relative Humidity Morning (%)	86.47	89.84	92.77	86.21	77.61	86.58	89.60	89.10	89.26	82.21	68.97	83.83
Relative Humidity Evening (%)	39.87	56.19	73.35	53.54	45.03	53.60	48.07	50.19	51.65	51.03	39.77	48.14
Wind Speed (km h^{-1})	1.46	1.90	2.79	2.23	3.48	2.37	1.23	1.93	1.59	2.53	2.78	2.01
Sunshine (h)	6.75	4.02	2.10	6.90	7.57	5.47	6.06	3.85	4.01	6.69	8.20	5.76
Evaporation (mm)	1.99	1.34	0.75	2.24	3.56	1.98	2.25	1.57	1.39	2.62	3.95	2.36

Reference: Meteorological observatory, Agricultural Institute Research Farm Department of Agronomy, IAS, BHU, Varanasi.

The recommended dose of fertilizers for the crop was 150:100:120 NPK kg ha^{-1} at basal application of ½ dose N + full dose of phosphorus + full dose of potash. Irrigation scheduling (I_1, I_2 & I_3) water applied at I_1 (3 irrigation) sprouting stage, tuber initiation stage and bulking stage, I_2 (4 irrigation) sprouting stage, tuber initiation stage, tuber elongation stage & bulking stage and I_3 (5 irrigation) sprouting stage, vegetation growth, tuber initiation, tuber elongation and tuber bulking stage. The applied four types (A_0, A_1, A_2 & A_3) of amino acid based biostimulants of (A_0) control, (A_1) animal based, (A_2) plant based and (A_3) mixture amino acid at three application schedule of amino acid on (Stage I) five leaves stage of the crop, (Stage II) tuber initiation stage and (Stage III) fifteen days after second stage of application.

Treatment combination

Treatment Symbol	Combinations (Irrigation × Amino acids biostimulants)
I_1A_0	3 irrigation × Control
I_1A_1	3 irrigation × Amino acids biostimulants originated from animal
I_1A_2	3 irrigation × Amino acids biostimulants originated from plant
I_1A_3	3 irrigation × Mixture of amino acids
I_2A_0	4 irrigation × Control
I_2A_1	4 irrigation × Amino acids biostimulants originated from animal
I_2A_2	4 irrigation × Amino acids biostimulants originated from plant
I_2A_3	4 irrigation × Mixture of amino acids

I_3A_0	5 irrigation × Control
I_3A_1	5 irrigation × Amino acids biostimulants originated from animal
I_3A_2	5 irrigation × Amino acids biostimulants originated from plant
I_3A_3	5 irrigation × Mixture of amino acids

All the biostimulants are in liquid formulation (250 mL of amino acid/100L of water, $ha^{-1)}$ and will be applied through sprayer, mixing/diluting with water. At the time of harvest tuber yield from each plot were weighed and expressed in kg/ha.
Water use efficiency (WUE) was determined by taking ETc and tuber yield (TY) using the following formula:

$$WUE = \frac{TY\ (kg/ha)}{ETc\ (mm/day)}$$ WUE = expressed as (kg /ha/ mm)

Estimating crop evapotranspiration (ETc) rate: (Allen *et al*., 1998)
ETc = ETo × Kc
Where,
ETc = crop evapotranspiration (mm /day)
ETo = reference crop evapotranspiration (mm /day)
Kc = crop coefficient (dimensionless)

Collection of Soil Samples
Soil samples collected from field preparation time and air dried at room temperature under shade. Air dried samples were grinded manually by wooden grinder and passed through a 2 mm sieve.

Analysis Method
Soil pH: The pH of soil was measured in 1: 2.5 (Soil: Water) suspension with the help of glass electrode digital pH meter (Jackson, 1973) [15].

Soil Electrical Conductivity: The soil water suspension was prepared in 1:2.5 (Soil: Water) ratio. The electrical conductivity of the filtrate of suspension was determined by electrical conductivity meter (Jackson, 1973) [15].

Bulk and Particle Density: The bulk and particle density were determined using pycnometer bottle in laboratory in disturbed soil sample (Black, 1965) [5].

Porosity of the soil: The per cent pore space of soil was calculated from data on bulk density and particle density. Porosity was determined by using the following equation:

$$P = \left(1 - \frac{d_b}{d_p}\right) \times 100$$

Where, P is the porosity of the soil, d_b is the bulk density of the soil and d_p is the particle density of the soil.

Mechanical Analysis and soil textural class: Mechanical analysis of soil was determined by Bouyoucos hydrometer method (Bouyoucos, 1962) [8]. Present sand, silt and clay were calculated and textural classes were determined with help of USDA textural triangle.

Water Holding Capacity: The water holding capacity (WHC) of the soils was measured in laboratory using Keen-Rackzowski box (Piper, 1966) [22].

Organic Carbon: Organic carbon content of the soils was estimated by Walkley [31] and Black, 1934 [7], method as stated by (Jackson, 1973) [15].

Available nitrogen: Available nitrogen content of soil was determined by alkaline permanganate method (Subbiah and Asija, 1956) [27].

Available Phosphorus: Available nitrogen content of soil was determined by (Watanabe and Olsen, 1965) [32] method.

Available Potassium: Available potassium of the soil samples was measured using flame photometer as described by (Hesse, 1971) [14].

Available Sulphur: Available sulphur in soil was determined by turbidity method (Chesnin and Yien, 1950) [9].

Results and Discussion
Yield of potato tuber
The effect of irrigation and amino acid based biostimulant interaction in potato tuber was observed in (fig. 1) indicated that the fresh yield of harvested potato tuber (kg/ha) was significantly affected by different interaction on irrigation schedules and amino acids biostimulant spraying. Variation in amino acids sources and irrigation levels influenced the tuber yield of potato in both the years. The maximum tuber yield (25500 and 24133.18 kg/ha, during first and second year, respectively) was recorded with I_2A_2 followed by other treatment combinations. Among the different irrigation schedules and amino acids biostimulant significantly lower yield (17900.00 and 17033.31 kg/ha, during first and second year, respectively) was noticed under I_1A_1 treatment combinations. The low yield may be due to water stress during tuber initiation and tuber bulking stages. Different amino acids biostimulant spraying also significantly improved the fresh tuber yield of potato. This may be due to metabolism of photosynthetic from source to sink (Singh and Sarkar, 1976) [26]. The results are in accordance with (Patil *et al*., 1996 [21], Basuchoudhari *et al*., 1986 [6] and Banet *et al*., 1972) [5]. Glycine and glutamic acid are fundamental metabolites in the process of vegetable tissues and chlorophyll synthesis. Moreover, the amino acid, glutamic acid acts as a cytoplasm osmotic agent of the "Guard cell". Thus favouring opening of the stomata (Abdel-Mawgond *et al.,* 2011) [1] also noticed that the similar yield improvement of green bean with the spraying two times of Amino-green (amino acids based product) on crop. The significant increase in fresh yield of potato tuber is attributed to adequate moisture in rhizosphere resulting in better uptake of nutrients with increased plant growth, yield and yield components. Similarly observed that the yield and yield contributing characters (Amanullah *et al*., 2010) [3] of high yielding potato varieties (Binella, Cardinal, Chamak and Heera) in Bangladesh were maximum under four irrigation schedule (IW/CPE: 1.00) in comparison to all the treatments of irrigation schedules (i.e. IW/CPE: 0.25, 0.50, 0.75 and 1.00).

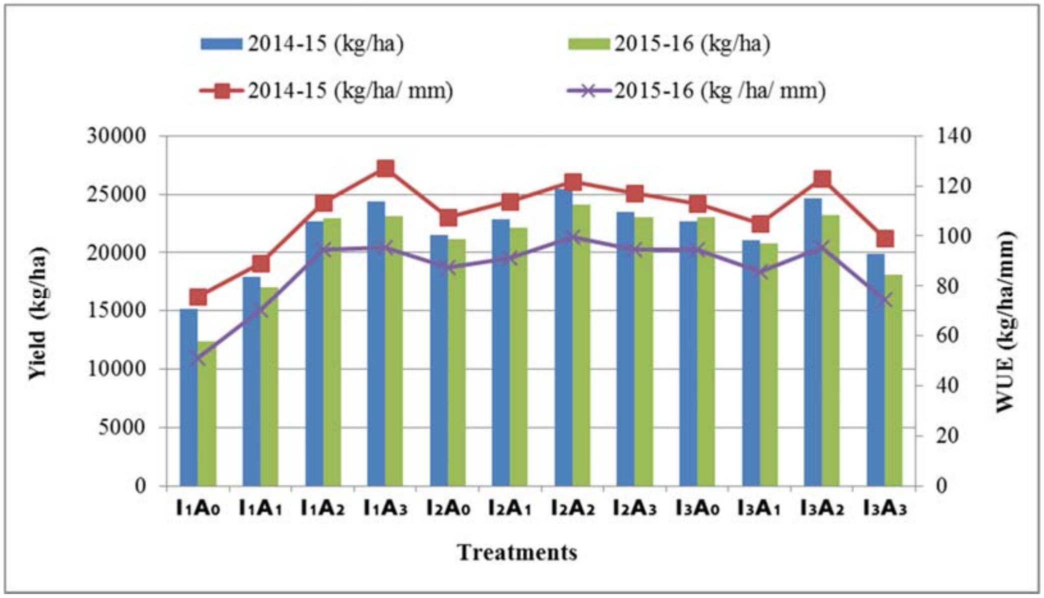

Fig 1: Effect of irrigation and amino acids based biostimulants on yield of tubers (kg ha^{-1}) and water use efficiency (WUE) in (kg ha^{-1} mm^{-1}) of potato crop

Water use efficiency

The term water use efficiency (WUE) denotes the production per unit of water used by the crop. The effect of three different levels of irrigation (I_1, I_2 & I_3) and three different sources of amino acids and their interaction have been presented in (fig.1), respectively. Water use efficiency was calculated as the ratio of the tuber yield and the total water used including irrigation applied, effective rainfall and soil profile moisture contribution. The interaction effect of irrigation schedule and amino acids based biostimulantsons on maximum WUE was observed (127.23 kg/ha/mm) in I_1A_3 treatment combination in 2014-15 and I_1A_3 was statistically at pan with I_2A_2 & I_3A_2 in the year 2014-15. In the year 2015-16, the maximum WUE was observed (99.41 kg/ha/mm) in I_2A_2 combination and I_2A_2 was statistically at pan with I_1A_3 & I_3A_2. Thus, in moisture stress condition I_2A_2 significantly improved the soil moisture status as well as WUE of potato crop compared to that of minimum irrigation system. Similarly, soil water depletion was decreased with concomitant increased the irrigation water applied with amino acids spraying. Thus the irrigation as well as amino acids application facilitated to decrease the soil moisture loses by way of evaporation and more water in subsurface soil profile for subsequent plant use. Maximum growth and yield are obtained when soil water supply is maintained at a high level around field capacity. The consumption use by crop under such condition occurs at a potential rate. These results are in close confirmation with the findings of (Mladenova *et al.,* 1998 [19] and Badr *et al.*, 2012) [4].

Yield and Water Use Efficiency Relationship

The interaction effect of irrigation and amino acid based biostimulants in the relationship of yield and WUE in potato tuber (fig 1) was observed for 3 irrigation schedule and animal based amino acid (I_1A_3) maximum yield and WUE in compression to I_1A_1 and I_1A_2 in both the year of experiment. The interaction effect of 4 irrigation schedule and plant based amino acid (I_2A_2) was observed maximum yield and WUE in compression to I_2A_1 and I_2A_3 in both the year of experiment and 5irrigation schedule was observed maximum yield and WUE in plant based amino acid (I_3A_2) in compression to I_3A_1 and I_3A_3 in both the year of experiment. All the interaction effect of irrigation and amino acids based biostimulants was observed yield maximum with WUE maximum and yield is low with WUE is low.

Organic biostimulants such as protein hydrolysates, humates, etc. (Sindhu *et al.,* 2015) [25] positively influences plant growth and metabolism; thereby, contributing towards higher crop yields. Hence, protein hydrolysates can be effectively used as organic fertilizers to improve productivity of the crops. The WUE decreased (Amanullah *et al*., 2010) [3] with the increase of water use or irrigation frequency. The high irrigation (Fandika, *et al.,* 2010) [11] reduced WUE but increased NUE. Similarly, high nitrogen reduced NUE but increased WUE in all cultivars.

Properties of the Soil in Experimental Site

The soil properties (table 2) in the field experimental site of soil reaction (soil pH) were noticed mildly alkaline (pH 8.0). The organic matter content, plant available nitrogen and potassium were found low range of rating chart for soil test values; whereas plant available phosphorus was in medium range.

Table 2: Physical and chemical properties of soil under study at sowing time

Parameter	2014-15	2015-16
pH $_w$ (1:2.5)	8.03	8.05
EC (1:2.5) (dSm^{-1})	0.255	0.257
Bulk density (Mg m^{-3})	1.35	1.36
Particle density (Mg m^{-3})	2.30	2.31
Porosity (%)	41.72	41.53
Textural class	Sandy loam	Sandy loam
Water Holding Capacity (%)	44.37	42.36
Organic Carbon (g kg^{-1})	4.6	5.0
Available N (kg ha^{-1})	144.23	150.26
Available P (kg ha^{-1})	24.29	28.14
Available K (kg ha^{-1})	119.90	135.19
Available S (kg ha^{-1})	19.33	19.48

The plant available sulphur was noticed above the critical level in experimental soil in both the years. The water holding capacity porosity in the soil was observed good for potato cultivation and textural class sandy loam. The physical and chemical conditions were conducive potato cultivation under irrigated condition of cultivation practice.

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