Journal of Crop Nutrition Science
ISSN: 2423-7353 (Print) 2538-2470 (Online)
Vol. 8, No. 2, 2022
https://jcns.ahvaz.iau.ir/ OPEN ACCESS

Determining the Effect of Different Level of Fertilizer and Tuber Weight on Quantitative Traits of Potato Cultivar under Warm and Dry Climate Condition

Mansour Timar[1,2*], Alireza Shokuhfar[2], Naser Zarifinia[3]

1- *Department of Agronomy, Khuzestan Science and Research Branch, Islamic Azad University, Ahvaz, Iran.*
2- *Department of Agronomy, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran.*
3- *Assistant Professor of Agricultural Engineering Research Department, Safiabad Agricultural, Research and Education and Natural Resources Center, Vegetable Research Center, Horticultural Sciences Research Institute Agricultural Research, Education and Extension Organization (AREEO), Dezful, Iran.*

RESEARCH ARTICLE

ARTICLE INFO.
Received Date: *16 Apr. 2022*
Received in revised form: *17 May. 2022*
Accepted Date: *18 Jun. 2022*
Available online: *30 Jun. 2022*

To Cite This Article: Mansour Timar, Alireza Shokuhfar, Naser Zarifinia. Determining the Effect of Different Level of Fertilizer and Tuber Weight on Quantitative Traits of Potato Cultivar under Warm and Dry Climate Condition. ***J. Crop. Nutr. Sci.,*** 8(2): 52-66, 2022.

ABSTRACT

BACKGROUND: The high cost of fertilizers has increased the production expenses so that the farmers are using imbalance fertilizers, which results in lower nutrients uptake and then lower quality of plants. Bio-fertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen, both, in association with plant roots and without it, insoluble soil phosphates and produces plant growth substances in the soil.

OBJECTIVES: This was study was done to assess the effect of nutrition matter (chemical and biologic fertilizer) and tuber weights on plant height, LAI and tuber yield.

METHODS: This research was carried out via split-split-plot experiment based on randomized complete blocks design with three replications. The main plots included feeding by chemical fertilizer and biofertilizer (a_1: 180 $kg.ha^{-1}$ nitrogen fertilizer from urea source, 150 $kg.ha^{-1}$ P_2O_5 from triple superphosphate source and 100 $kg.ha^{-1}$ potassium from potassium sulfate source, a_2: 1 $kg.ha^{-1}$ humic acid and 100 grams per hectare phosphorus biofertilizer, a_3: chemical fertilizer, humic acid and phosphorus biofertilizer). The sub-plots included three tuber weights (b_1: small or less than 75g, b_2: medium or between 70-140g, b_3: large or more than 10g), and potato cultivar (c_1: Arinda, c_2: Savalan and c_3: Sante) belonged to sub-sub-plots.

RESULT: According result of analysis of variance effect of fertilizer (instead plant height), tuber yield and cultivar on studied traits was significant. The results showed that the highest potato yield of 33.4 tons per hectare was obtained in the Savalan cultivar with tuber size less than 75 grams and feeding with humic acid + phosphorus biofertilizer, which was not significantly different from the Sante variety with the same nutritional conditions and tuber size (33.06 tons per hectare).

CONCLUSION: In general, the use of phosphorus biofertilizer and humic acid improved the studied characteristics of potatoes in the climatic conditions of North Khuzestan. Therefore, it is recommended to use mentioned fertilizers and Savalan cultivar with a tuber size of less than 75 grams in these areas.

KEYWORDS: *Leaf area, Nitrogen, Phosphorus, Potassium, Tuber yield.*

***Corresponding Author:** Mansour Timar ✉ m.timar2018@gmail.com

1. BACKGROUND

Obtaining high potato tuber yield through increasing the number and weight of quality tubers is necessary. Potato quality factors including dry matter, starch and protein content are important to food industry. For example, if potato products are to be processed at high temperatures, they should have high and low levels of starch and sugars, respectively (Bent *et al*., 2012). To this aim, good management practices are requirements, which eventually lead to adequate canopy formation, assimilate for stolons, tuberization and high quality tuber formation. Organic farming has emerged as an important priority area globally in view of the growing demand for safe and healthy food and long term sustainability and concerns on environmental pollution associated with indiscriminate use of agrochemicals. Though the use of chemical inputs in agriculture is inevitable to meet the growing demand for food in world, there are opportunities in selected crops and niche areas where organic production can be encouraged to tape the domestic export market (Venkatash-Warlu, 2008). In organic agriculture, one management goal is to increase and maintain soil quality with a high biological activity. Organic cropping system often has to deal with a scarcity of readily available nutrients in contrast to high input cropping system which relies widely available on soluble fertilizers (Soleimanzadeh and Ghooshchi, 2013). Nutrient management may be achieved by the involvement of organic sources, bio-fertilizers, and micronutrients (Singh *et al*., 2002). Indiscriminate use of chemical fertilizers to achieve high yield and to compensate for lack of nutrients and consequently the increase of production costs and destruction of soil and water resources have made the specialists interested in healthy and stable crop systems in terms of ecology (Tilak *et al*., 1992). More recently, a real challenge faces the workers in the agricultural research field to stop using the high rates of agro-chemicals which negatively affect human health and environment (El-Kholy *et al*., 2005; Kader *et al*., 2002). Farming practices which involve heavy application of chemical fertilizers may cause depletion of certain nutrients in soil and certain others would generally accumulate in excess resulting in nutrient imbalance which affects the soil productivity. Some of these problems can be tackled by using bio-fertilizers, which are natural, beneficial and ecologically friendly. Among the means available to achieve sustainability in agricultural production, organic manure and bio-fertilizer play an important and key role because they possesses many desirable soil properties and exerts beneficial effect on the soil physical, chemical and biological characteristics of the soil. he application of bio-fertilizers has become of great necessity to get a sufficient yield with high quality to avoid environmental pollution (Shevananda, 2008). Bio-fertilizers most commonly referred to as the fertilizer that contains living soil micro-organisms to increase the availability and uptake of mineral nutrients for plants (Vessey, 2003). It is expected that their activities will influence the soil ecosystem and produce supplementary substance for the plants. Bio-fertilizers also include organic fertilizers, which are rendered in an available form due to the interaction of microorganisms or due to their association with plants (Sujanya and Chandra, 2011). When bio-fertilizers are applied as seed or soil inoculants, they multiply and participate in nutrient cycling and benefit crop productivity (Singh *et al*., 2011). Bio-fertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen, both, in association with plant roots and without it, insoluble soil phosphates and produces plant growth substances in the soil. They are in fact being promoted to harvest the naturally available, biological system of nutrient mobilization (Venkatash-Warlu, 2008). Abd-Alrahman Rehab *et al*. (2002) stated that use of phosphorus bio-fertilizer in wheat, compared with chemical fertilizers, led to reduction of chemical fertilizer consumption, increase of product, uniformity of the farm, thickness of stems, increase of spikes length, plant resistance to diseases and frost, increase of tillering and ultimately decrease of environmental damage. Qing-Fang *et al*. (2020) reported combination of organic and inorganic fertilization maintained high rice yield, and also produced a more complex and stable phosphate mobilizing bacterial community, which contributed to phosphatase activities more than their gene abundances in the model analysis. Nouraki *et al*. (2016) reported mixing of biological fertilizers with chemical fertilizers could reduce the needs of chemical fertilizers up to 25% and these results are comparable to the application of 100% chemical fertilizers. Therefore, the best hybrid maize is the single cross 704 that has good yield potential when the chemical fertilizer is used at either 25% or 50% of the current application when mixed with the bio-fertilizer. Zhang *et al*. (2020) to help minimize the negative impact of chemical fertilizers on the environment, recycle nitrogen and phosphorus nutrients of anaerobic digestate and reduce loss of nutrients via leaching, an eco-friendly slow-release fertilizer was prepared through recovery of nitrogen and phosphorus nutrition from digestate using superabsorbent fibers extracted from soybean curd residue as an adsorbent reported The successful incorporation of N and P into the fiber composite-based adsorbent via adsorption was confirmed by results of these analyses. The prepared fertilizer showed a relatively high N content (3.65 wt%) and a limited P content (0.14 wt%). Also, the swelling capacity as well as water retention capability of the obtained fiber composite-based adsorbent were evaluated. All organic manures improve the behaviors of several elements in soils through that active group (Humic acids; HA) which have the ability to retain the elements in complex and chelate form. These materials release the elements over a period of time and are broken down slowly by soil microorganisms. The extent of availability of such nutrients depends on the type of organic materials and microorganisms (Ghavidel Shahraki *et al.,* 2017). Humic acid is extracted from different sources, such as humus and, soil and using chelating essential elements improve and increase fertility and productivity of soil, especially in conditions of stress (Ghadimian *et al*., 2017). Humic compounds such as fulvic acid and humic acid are formed by chemical and microbial degradation of plant and animal material and are a principal component of soil organic matter. In general, the application of fulvic and humic acid fertilizer amendments have been shown to enhance root growth, increase nutrient uptake, alleviate stress, and increase yield in various crops (Canellas *et al*., 2015). Humic acid well known in controlling, soil-borne diseases, improves the physical, chemical and biological properties of the soil and influences plant growth, soil health and nutrient uptake by plants, mineral availability, fruit quality, etc. Humic substances are recognized as a key component of soil fertility properties, since they control chemical and biological properties of the rhizosphere (Trevisan *et al*., 2009; Mauromicale *et al*., 2011). Humic acid is water-soluble organic acid naturally present in soil organic matter. It can be recognized that humic substances (HS) have many beneficial effects on soil structure and soil microbial populations, as well as, increase modify mechanisms involved in plant growth stimulation, cell permeability and nutrient uptake causing increases (Atiyeh *et al*., 2000; Rahmat *et al*., 2010). Application of the humic acid had statistically significant effect on Mg, Fe and Mn uptake. Humic acid raised the dry weight and N, P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn uptake of plants at non limed pots and the amounts were found high at 0.1 % dose of humic acid. The second dose (0.2 %) was found much more effective on dry weight and nitrogen uptake at high lime conditions (Katkat *et al*., 2009). The mechanism of humic acid activity in promoting plant growth is not completely known, but several explanations have been proposed by some researchers such as increasing cell membrane permeability, oxygen uptake, respiration and photosynthesis, phosphate uptake, and root cell elongation (Turkmen *et al*., 2004). Also Delfine *et al*. (2005) investigated the effect of application of humic acid on growth and yield of durum wheat. Moreover, they specified that the application of humic acid caused a transitional production of plant dry mass with respect to unfertilized control.

2. OBJECTIVES

The current research was conducted to study the effect of nutrition matter (chemical fertilizer and biologic fertilizer) and tuber weights on plant height, LAI and tuber yield.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This research was carried out via split-split-plot experiment based on randomized complete blocks design with three replications along 2016 and 2017 year. Place of research was located in Safi Abad Dezful Agricultural Research Center at longitude 48°26'E and latitude 32°16'N in Khuzestan province (Southwest of Iran). The main plots included feeding by chemical fertilizer and biofertilizer (a_1: 180 kg.ha^{-1} nitrogen fertilizer from urea source, 150

$kg.ha^{-1}$ P_2O_5 from triple superphosphate source and 100 $kg.ha^{-1}$ potassium from potassium sulfate source, a_2: 1 $kg.ha^{-1}$ humic acid and 100 grams per hectare phosphorus biofertilizer, a_3: chemical fertilizer, humic acid and phosphorus biofertilizer). The sub-plots included three tuber weights (b_1: small or less than 75g, b_2: medium or between 70-140g, b_3: large or more than 10g), and potato cultivar (c_1: Arinda, c_2: Savalan and c_3: Sante) belonged to sub-sub-plots. Physical and chemical properties of the soil are mentioned in table 1.

3.2. Farm Management

To apply phosphorus biologic fertilizer, the biofertilizer (100 $gr.ha^{-1}$) was dissolved in a 10 liter container filled with water. Then the seeds were placed in these containers for 10 minutes before planting and impregnated with fertilizer solution and then they were planted. Phosphorus biofertilizer (brand Barvar 2) contains 10^7 to 10^8 phosphate-solubilizing bacteria (*Pantoea* agglomerans strain P5 and Pseudomonas strain P13) per gram of product, which are released phosphates ions by producing organic acids and phosphatase enzymes around the roots. During the planting, separate disposable gloves for each treatment were used to prevent mixing of the effects of treatments. Other fertilizers were used as the base. Hubest® organic fertilizer, obtained from Hasel Novin Agriculture Company used as a source of humic acid which contains K_2O (8.0%), humic and fulvic acid (60%), sulfur (3.7%), iron (1.2%) and MgO (0.2%).

Table 1. Physical and chemical properties of studied field and water

Sample	Soil depth (cm)	EC ($dS.m^{-1}$)	pH	OC (%)	K ($mg.kg^{-1}$)	P ($mg.kg^{-1}$)
Soil	0-30	2.5	7.84	0.29	69	2.5
Water	**EC ($dS.m^{-1}$)**		**pH**	**Ca+Mg ($mg.l^{-1}$)**	**Na ($mg.l^{-1}$)**	**K ($mg.l^{-1}$)**
	0.4		7.70	69	105	2.4

3.3. Measured Traits

A leaf area meter (Li-3000c portable) was used to measure the leaf area index. The number of 4 potato plants was selected from the middle lines of each plot and the height of all 4 stems was recorded at the time of flowering and ripening. In order to determine the tuber dry weight of the plant, the plants that were assigned for this purpose were sampled and after being transferred to the laboratory, the leaves are separated from the rest of the plant organs. To determine the dry weight, the samples of the aerial parts were placed in an oven at a temperature of 75 degrees Celsius for 72 hours and then weighed. In order to determine the potato yield, after completion of the growing season and ripening potato tubers, the middle two rows of plants (inside plots) were collected during a meter entirely. Each samples were separately and put in special bags and placed at oven for 72 hours at 75°C and after drying completely, it's were weighed with a balance with precision of 0.001g.

3.4. Statistical Analysis

Analysis of variance and mean comparisons were done via SAS (Ver.8) software and Duncan multiple range test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. *Plant height*

According result of combined analysis of variance effect of tuber weight and cultivar on plant height was significant at 5% and 1% probability level, respectively, but effect of fertilizer and interaction effect of treatments was not significant (Table 2). Mean comparison result of different level of tuber weight indicated that maximum plant height (73.67 cm) was noted for b_3 (large or more than 10g) and minimum of that (64.26 cm) belonged to b_1 (small or less than 75g) treatment, also it doesn't had significant difference with b_2 (medium or between 70-140g) treatment (Table 3). As for Duncan classification made with respect to different level of cultivar maximum and minimum amount of plant height belonged to Savalan (79.44 cm) and Arinda (55.67 cm) (Table 3). The increase in the plant height in the humic acid amended treatments most probably was due to the improvement of growth of the root zone. With increasing drought stress, the plant height decreased due to lack of plant access to the amount of water suitable for growth, also with increase in humic acid level, plant height increased. The amount of this decline is influenced by the genetic factors and varies depending on the cultivar. Drought stress decreases leaf area, stomata obstruction, protoplasmic activity and carbon fixation and decreasing photosynthesis, which ultimately reduces plant height (Qurbani *et al*., 2010). Nasiri *et al*. (2022) reported results of factor analysis based on studied traits in the aeroponic culture experiment showed that in weight and number of mini tubers, number of stems, number of stolon increased by application of chemical fertilizer and plant height and stolon length due to biological fertilizer application. Among cultivars, cv. Banba showed the highest yield (number and weight of mini tubers 162, 1135 g,) with chemical fertilizer application. According to the results of factor analysis of field experiment, the use of *A. lipoferum* significantly increased the number of tuber, tuber weight, number of stems and growth indices of total dry weight, tuber dry weight, crop growth rate, tuber growth rate and leaf area, and A. chroococcum had an increasing effect on plant height and number of stolon. In field experiment, the highest yield (number and weight of tuber were 24,800 g,) according to traits and growth indices in Agria cultivar with application of *A. lipoferum* bacteria. Based on the current research findings, chemical fertilizers application in aeroponic cultivation and treating with *A. lipoferum* in field improve potato yield. Shafeek and colleges (2013) evaluated the effects of humic acid on wheat shoot and root growth and found that 300 mg humic acid has the greatest effects on roots and shoot growth. Further, Haghparast and Maleki-Farahani (2013) have reported that 50 $mg.L^{-1}$ humic acid can caused elongation in the root cell of pea plants. According to (Boraste, 2009) plant height and plant diameter in corn increase much more in the effect of inoculation with *Azotobacter* and *Azospirillum* bacteria than non-inoculated. Besides, inoculation of wheat seeds with bacteria such as *Azotobacter* and *Azospirillum* can lead to stem dry weight, and dry weight of plant (Defreitas, 2000).

4.2. *Leaf area index* (*LAI*)

Result of combined analysis of variance showed effect of fertilizer, tuber weight, cultivar and interaction effect of treatments on leaf area index was significant at 1% probability level (Table 2). Multiple mean comparison of interaction effect result revealed in the second year of the study, we saw a significant increase in the leaf area index compared to the first year of the study.

Table 2. Result of combined analysis of variance effect of treatment on studied traits

S.O.V	df	Plant height	Leaf area index	Tuber dry matter	Tuber yield
Year (Y)	1	702.7^{ns}	10.2**	252.2**	339.3**
Replication (R)	4	132.9^{ns}	14.5**	33.4	59.7
Fertilizer (F)	2	691.1^{ns}	3.0**	226.4**	287.0**
Y × F	2	46.6^{ns}	0.74**	13.5^{ns}	28.2^{ns}
Error I	8	407.4	2.81	53.6	39.4
Tuber weight (T)	2	1233.1*	0.62**	89.3**	122.5**
Y × T	2	20.8^{ns}	0.05**	2.07**	0.86^{ns}
F × T	4	71.3^{ns}	3.1**	137.9**	65.6**
Y × F × T	4	24.1^{ns}	0.25**	4.5**	7.5^{ns}
Error II	24	17.6	0.10	0.06	1.82
Cultivar (C)	2	7769.4**	6.2**	23.8**	115.5**
Y × C	2	54.1^{ns}	0.27**	2.2**	5.6^{ns}
F × C	4	130.8^{ns}	5.5**	22.7**	11.3*
Y × F × C	4	4.5^{ns}	0.14**	2.1**	2.5^{ns}
T × C	4	167.8^{ns}	6.3**	138.9**	10.6*
Y × T × C	4	11.3^{ns}	0.2**	7.01**	4.9^{ns}
F × T × C	8	75.7^{ns}	0.6**	83.4**	11.5**
Y × F × T × C	8	14.1^{ns}	0.2**	6.6**	5.7^{ns}
Error III	104	311.9	0.01	0.033	3.31
CV (%)	-	25.7	2.26	0.26	7.04

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

In both crop years, feeding with humic acid + phosphorus biofertilizer had the highest LAI and the lowest amount of this parameter was seen in the treatment with chemical fertilizer. Among the investigated cultivars, in the first year of the research, Arinda cultivar and after that Savalan were in better conditions in terms of leaf area index, and Sante cultivar had the lowest value of this index in the first year. In the second year of research, Sante and Arinda cultivars had better conditions and Savalan cultivar had a smaller LAI. While the size of the small tuber in Sante variety in the first year and feeding with chemical fertilizer had the lowest value of leaf area index (by 2.3), The small tuber size in the same variety and the nutrition treatment in the second year had a higher LAI compared to the other two tuber weights. The highest LAI was achieved in the treatment of Arinda variety with small seed size and feeding with biofertilizers and in the second year of the research were 6.4, which has no significant difference with Sante variety and average seed size in the same nutritional treatment (LAI=6.2) (Table 4). Ghadimian *et al*. (2017) by evaluate effect of irrigation halt and humic acid on physiological characteristics of red bean reported the highest seed yield was in complete irrigation and irrigation halt at pod stage and lowest rate was for irrigation halt at flowering stage. Use of humic acid in normal conditions and in conditions of hold irrigation at flowering and pod stage could be increasing the seed yield. Chavoshi *et al*. (2016) by evaluation responses of red bean cultivars to halt irrigation reported halt irrigation could be reduced seed yield from 2624.73 kg ha^{-1} in full irrigation to 1632.82, 1088.55 and 2301.85 kg ha^{-1} irrigation halt at vegetative growth, flowering and pod filling stages respectively. Rahi (2013) reported that increase in Nitroxin also increased fresh and dry weights of leaf, stem, chlorophylls a, b, total carotenoids, and anthocyanin content of the plants linearly. Garg *et al.* (2005) reported increasing nitrogen to soil led to increase the plant photosynthetic efficiency and ultimately increased the seed yield and growth rate. On the other hand, since the rate of light absorption by leaves and converting it into photosynthetic materials are the other factors affecting the plant growth and production, the increase of leaf area in the farm leads to the increase of light absorption and ultimately leads to the increase of seed yield.

Table 3. Mean comparison effect of different level of tuber weight and cultivar on plant height

Plant height (cm)	Tuber weight			Cultivar		
	b_1	b_2	b_3	c_1	c_2	c_3
	64.26b*	67.56b	73.67a	55.67c	79.44a	70.38b

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).
Tuber weights (b_1: small or less than 75g, b_2: medium or between 70-140g, b_3: large or more than 10g).
potato cultivar (c_1: Arinda, c_2: Savalan and c_3: Sante).

4.3. *Tuber dry matter* (*TDM*)

According result of combined analysis of variance effect of fertilizer, tuber weight, cultivar and interaction effect of treatments on tuber dry matter (instead year × fertilizer) was significant at 1% probability level (Table 2). In the second year, the percentage of potato dry matter increased significantly, and in the second year, we saw an increase in potato yield, which is probably due to favorable weather conditions and the effect of biofertilizers in the second year of research. Among the nutrition treatments, the feeding treatments with humic acid+ phosphorus biofertilizer had a higher percentage of dry matter than other nutritional treatments, and the nutrition treatment with chemical fertilizer + humic acid+ phosphorus biofertilizer was in the next rank. The small tuber size led to a higher dry matter percentage in all nutritional treatments and crop year, which was not significantly different from the average seed size treatment in most treatments, especially the feeding treatments with humic acid + phosphorus biofertilizer. Savalan and Sante cultivars had higher percentage of dry matter in most nutritional treatments, tuber size and year of cultivation, and Savalan cultivar had better conditions in terms of dry matter percentage. In total, Savalan variety with small seed size in the second year of research and feeding with humic acid + phosphorus biofertilizer had a higher percentage of dry matter than other treatments by the amount of 33.6% (Table 4).

Table 4. Mean comparison interaction effects of year, fertilizer, tuber weight and cultivar on LAI and TDM

Year	Fertilizer	Tuber weight	Leaf area index (LAI)			Tuber dry matter (TDM)		
			Cultivar			Cultivar		
			c_1	c_2	c_3	c_1	c_2	c_3
First	a_1	b_1	4c	4.5c	3.2d	23.7c	25.4c	24.7c
		b_2	3.9d	5b	4.2c	28b	32.5b	29b
		b_3	4.2c	4.4c	4.8c	21.6e	21.6e	20f
	a_2	b_1	5.1b	5.1b	4c	12.1h	23.8d	24.6c
		b_2	4c	3.4d	3.2d	21.7e	21.1e	18.8f
		b_3	4.9c	4.6c	5.3b	17.1g	19.3f	23.2d
	a_3	b_1	3.5d	4.4c	3.1d	25.9c	24.5cd	16.9g
		b_2	4.6c	3.3d	4.4c	24cd	24.4cd	24.4cd
		b_3	3.7d	3.9d	5.1b	26.1c	24.1cd	27.2bc
Second	a_1	b_1	4c	5.4b	5.3b	28.5b	27.8bc	18.8g
		b_2	5.5b	4.9c	3.8d	28.5b	27.9bc	18.6g
		b_3	4.8c	3.6d	4.4c	27.4bc	27.3bc	27.5bc
	a_2	b_1	6.4a	5.3b	6a	26.2c	22.1e	23.2d
		b_2	5.8b	5.29b	6.2a	24.8c	23.6d	21.5f
		b_3	3.8d	3.44d	4.6c	18.8f	22e	25.5c
	a_3	b_1	3.89d	5b	5b	26.6c	33.6a	30.8b
		b_2	5.24b	3.78d	5.6b	26.6c	20.5g	24.9c
		b_3	4.13c	4.44c	5.7b	13.8i	26.7c	30.3b

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).

Chemical fertilizer and biofertilizer (a_1: 180 $kg.ha^{-1}$ nitrogen fertilizer from urea source, 150 $kg.ha^{-1}$ P_2O_5 from triple superphosphate source and 100 $kg.ha^{-1}$ potassium from potassium sulfate source, a_2: 1 $kg.ha^{-1}$ humic acid and 100 grams per hectare phosphorus biofertilizer, a_3: chemical fertilizer, humic acid and phosphorus biofertilizer).

Tuber weights (b_1: small or less than 75g, b_2: medium or between 70-140g, b_3: large or more than 10g).

Potato cultivar (c_1: Arinda, c_2: Savalan and c_3: Sante).

Sadra *et al*. (2022) reported maximum tuber yield obtained in vetch with application of 66 percent of nitrogen fertilizer (35.42 t.ha^{-1}) and the least tuber nitrate (31.92 mg.kg^{-1}) was measured in control (without nitrogen fertilizer). Application of nitrogen fertilizer had a significant negative effect on nitrogen use efficiency as the highest nitrogen use efficiency (94.78 kg.kg^{-1}) was obtained by inclusion of vetch as cover crop and without application of nitrogen fertilizer. In conclusion, our findings showed the positive effect of cover crops along with application of optimum level of nitrogen fertilizer on tuber yield potato, plant height and number of main stem per plant. This can be considered as a crop management package that leads to the reduction of application of chemical fertilizers, prevents its adverse effects on environment and more economic benefits for farmers. Azimi *et al*. (2013a) found that application of super nitroplass bio-fertilizer with Phosphate barvar2 treatment has the highest seed yield (7.6 t.ha^{-1}) and non-application of bio-fertilizers treatment has the Pishtaz cultivar has the lowest seed yield (6.3 t.ha^{-1}). Azimi *et al*. (2013b) was reported that grain yield and biomass yield increasing with the bio fertilizer application, also which account important benefit, causing decreasing in the inputs of production because of economizing much money to chemical fertilizers and increasing in yield and biological yield.

4.4. *Tuber yield*

Result of combined analysis of variance showed effect of fertilizer, tuber weight and cultivar on tuber yield was significant at 1% probability level (Table 2). The mean comparison results revealed effect of the year of cultivation on potato yield in the second year, was improved significantly (31.3%) compared to the first year, which could be due to favorable climatic conditions in the second year of research. Compare different level of chemical and biologic fertilizer showed that the feeding treatment with humic acid + phosphorus biofertilizer had better conditions than the other two treatments and the lowest one was obtained in the treatment using chemical fertilizer. Also, among different tuber sizes, the highest amount was obtained in small seed size, which did not have a significant difference in the humic acid + phosphorus biofertilizer feeding treatment with medium seed size. The large tuber size had the lowest yield in all nutritional treatments. Among the investigated cultivars, Savalan had a higher yield than the other two cultivars, Arinda and Sante, and in all nutrition treatments and tuber size, Savalan had the highest potato yield. Therefore, the highest potato yield of 33.4 t.ha^{-1} was obtained in Savalan variety with small tuber size and feeding with humic acid + phosphorus biofertilizer, so did not have a significant difference with Sante variety at the same nutritional conditions and tuber size (33.06 t.ha^{-1}) (Table 5). Azamshah *et al*. (2016) reported among all the mentioned treatments, maximum tuber yield was obtained in the treatment receiving half NPK (soil applied) and humic acid 0.03% (foliar applied).

Table 5. Mean comparison interaction effects of fertilizer, tuber weight and cultivar on yield

Fertilizer	Tuber weight	Tuber yield ($t.ha^{-1}$) Cultivar c_1	c_2	c_3
a_1	b_1	22.3f	27.05c	23.1e
	b_2	25.1d	23.3e	24e
	b_3	21.5g	25.5d	25.1d
a_2	b_1	30.9b	33.4a	33.0a
	b_2	27.1c	30.3b	27.3c
	b_3	23.3e	27.1c	24.4de
a_3	b_1	25.3d	28.7bc	24.5de
	b_2	23.5e	26cd	22.2f
	b_3	23.1ef	27.4c	23.5e

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).
Chemical fertilizer and biofertilizer (a_1: 180 $kg.ha^{-1}$ nitrogen fertilizer from urea source, 150 $kg.ha^{-1}$ P_2O_5 from triple superphosphate source and 100 $kg.ha^{-1}$ potassium from potassium sulfate source, a_2: 1 $kg.ha^{-1}$ humic acid and 100 grams per hectare phosphorus biofertilizer, a_3: chemical fertilizer, humic acid and phosphorus biofertilizer).
Tuber weights (b_1: small or less than 75g, b_2: medium or between 70-140g, b_3: large or more than 10g).
Potato cultivar (c_1: Arinda, c_2: Savalan and c_3: Sante).

Maximum N and P content in potato tubers were also found in the same treatment. Results showed that half NPK (soil applied) + foliar application of humic acid (0.03%) are economical and beneficial for the farmers. Aien and Jalali (2018) reported Sante and Satina cultivars produced the highest marketable tuber yield in normal condition (47.15 and 44.9 $t.ha^{-1}$, respectively), but under heat stress conditions, the difference between marketable tuber yield of those cultivars was not significant. The application of calcium nitrate improved marketable, non-marketable and total tuber yield and its components in potato cultivars and soil application of 75 $kg.ha^{-1}$ of calcium nitrate was significantly superior to the other treatments. The interaction effect of terminal heat stress and calcium nitrate applications on marketable and total tuber yield, mean weight and number of marketable and non-marketable tuber was significant. Soil application of calcium nitrate (75 $kg.ha^{-1}$) increased marketable tuber yield of potato cultivars under normal and terminal heat stress conditions (10.5 and 24.5%, respectively) that revealed the mitigating effect of calcium nitrate on terminal heat stress in potato cultivars. It concluded that soil application of calcium nitrate seems to be an appropriate method to reduce the adverse effects of terminal heat stress in winter potato production. Waqas *et al*. (2014) by evaluate effect of humic acid on yield of Mungbean reported 3 $kg.ha^{-1}$

humic acid resulted in a higher number of pods per plant, thousand grain weights and grain yield, however it was statistically similar to the treatments where humic acid was soil applied at rate of 1 and 2 kg.ha^{-1}, seed priming with (water soaked), 0%, 1%, 2% of humic acid solution and foliar spray with 0.01%, 0.05% and 0.1% of humic acid solution.

5. CONCLUSION

In general, the use of phosphorus biofertilizer and humic acid improved the studied characteristics of potatoes in the climatic conditions of North Khuzestan. Therefore, it is recommended to use mentioned fertilizers and Savalan cultivar with a tuber size of less than 75 grams in these areas.

ACKNOWLEDGMENT

The authors thank colleagues and other participants, who took part in the study.

FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

CONFLICT OF INTEREST: Authors declared no conflict of interest.

FUNDING/SUPPORT: This study was done by support of Department of Agronomy, Islamic Azad University, Ahvaz Branch.

REFRENCES

Abd-Alrahman Rehab, A., M. M El-Hady .and A. M. Abdelghany. 2002. Effect of timing of first irrigation and application of zinc and manganese on growth and yield of faba bean (*Vicia faba*. L) Giza blanka cultivar. J. Agric. Res. 35: 53-72.

Aien, A. and A. Jalali. 2018. Effect of calcium nitrate on yield of potato (*Solanum tuberosum* L.) cultivars under terminal heat stress condition in south of Kerman province. J. Iran Agricultural Res. 20(3): 193-208. (Abstract in English)

Atiyeh, R. M., S. Subler, C. A. Edwards, G. Bachman, J. D. Metzger. and W. Shuster. 2000. Effects of vermin-composts and compost on plant growth in horticultural. Container Media and Soil Pedobiologia. J. 44: 579–590.

Azam Shah, S., W. Mohammad, S. Shahzadi, R. Elahi, A. Ali, A. Basir. and Haroon. 2016. The effect of foliar application of urea, humic acid and micronutrients on potato crop. J. Iran Agricultural Res. 35(1): 89-94. (Abstract in English)

Azimi, S. M., A. Farnia, M. Shaban. and M. Lak. 2013a. Effect of different bio-fertilizers on seed yield of barley, Bahman cultivar. Intl. J. Adv. Biol. Biomedical Res. 1(5): 538-546.

Azimi, S. M., E. Nabati, M. Shaban. and M. Lak. 2013b. Effect of N and P bio fertilizers on yield components of barley. Intl. J. Adv. Biol. Biomedical Res. 2(2): 365-370.

Bent, G. A., P. Maragh. and T. Dasgupta. 2012. Acrylamide in Caribbean foods–Residual levels and their relation to reducing sugar and asparagine content. Food Chemistry. 133(2): 451-457.

Boraste, A. 2009. Bio-fertilizer: a novel tool for agriculture. Intl. J. Microbial. Res. 1(2): 23-31.

Canellas, L. P., F. L. Olivares, N. O. Aguiar, D. L. Jones, A. Nebbioso, P. Mazzei. and A. Piccolo. 2015. Humic and fulvic acids as biostimulants in horticulture. Sci. Hortic. 196: 15-27. Doi: 10.1016/j. scienta.2015.09.013

Chavoshia, S., Gh. Nourmohammadi, H. Madani, H. Heidari sharif abad. and M. Alavi fazel. 2016. Halt irrigation and red bean (*Phaseolus vulgaris* L.) cultivars responses. Natl. Acad. Agri. Sci. 4(7): 2203-2211.

Defreitas, J. R. 2000. Yield and N assimilation of winter wheat (*Triticum aestivum* L.) inoculated with rhizobacteria. Pedobiologia. J. 44: 97-104.

Delfine, S., R. Tognetti, E. Desiderio. and A. Alvino. 2005. Effect of foliar application of N and humic acids on growth and yield of durum wheat. Agron. Sustainable Develop. J. 25: 183-191.

El-Kholy, M. A., S. El-Ashry. and A. M. Gomaa. 2005. Bio-fertilization of maize crop and its impact on yield and grains nutrient content under low rates of mineral fertilizers. J. Appl. Sci. Res. 1(2): 117-121.

Garg, B. K., S. Kathju. and S. P. Vyas. 2005. Salinity-fertility interaction on growth. Photosynthesis and nitrate reductase activity in sesame. Indian J. Plant Physiol. 10: 162-167.

Ghadimian, T., H. Madani. and M. Gomarian. 2017. Effect of irrigation halt and humic acid foliar application on agronomic, qualitative and physiological characteristics in red bean cultivar D_{81083}. Iranian J. Pulses Res. 8(2): 141-155. (Abstract in English) DOI: 10.22067/ijpr.v8i2.53136

Ghavidel Shahraki, M., H. R. Ganjali. and S. M. Javadzadeh. 2017. Effect of manure and foliar application of humic acid on yield and yield component of Nigella sativa. Intl. J. Agri. Bio-Sci. 6(1): 25-27.

Haghparast, M. and S. Maleki Farahani. 2013. Effect of water deficit irrigation and natural vegetative characteristics of different products on Chickpea (*Cicer arietinum* L.) varieties. Iranian J. Pulses Res. 4: 77-86. (Abstract in English)

Kader, M. A., M. H. Mian. and M. S. Hoque. 2002. Effect or Azotobacter inoculant on the yield and nitrogen uptake by wheat. J. Biol. Sci. 4: 259-261.

Katkat, A. V., H. Celik, M. A. Turan. and B. B. Asik. 2009. Effects of soil and foliar applications of humic substances on dry weight and mineral nutrients uptake of wheat under calcareous soil conditions. Aust. J. Basic Appl. Sci. 3(2): 1266-1273.

Mauromicale, G., M. G. L. Angela. and A. L. Monaco. 2011. The effect of organic supplementation of solarized soil on the quality of tomato. Scientia Horti. J. 129(2): 189-196.

Nasirii, A., M. Yarnia, D. Hassanpanah, F. Farahvash. and E. Khalilvand. 2022. Evaluation of growth and yield of *Solanum tuberosum* L. cultivars due to application of plant growth promoting Rhizobacteria (PGPRs) and chemical fertilizer in Aeroponic culture system and field conditions: using exploratory factor analysis. Crop Physiology J. 14(53): 101-119. (Abstract in English)

Nouraki, F., M. AlaviFazel, A. Naderi, E. Panahpoor. and Sh. Lack. 2016. Effects of Integrated Management of Bio and Chemical Fertilizers on Yield of Maize Hybrids (*Zea mays* L.). J. Exp. Biol. Agric. Sci. 4(4): 421.426.

Qing-Fang, B, L. Ke-Jie, Zh. Bang-Xiao, L. Xi-Peng, Li. Hong-Zhe, J. Bing-Jie, D. Kai, Y. Xiao-Ru, L. Xian-Yong. and Zh.Yong-Guan. 2020. Partial replacement of inorganic phosphorus (P) by organic manure reshapes phosphate mobilizing bacterial community and promotes P bioavailability in a paddy soil. Sci. Total Environment. 703: 134977.

Qurbani, S., H. R. Khzaee, M. Kafi. and M. Banayan Aval. 2010. Effect of application humic acid in Irrigation water on seed yield and its components of corn. Agro Ecological. J. 23: 123-131. (Abstract in English)

Rahi, A. R. 2013. Effect of nitroxin biofertilizer on morphological and physiological traits of *Amaranthus retroflexus*. Iranian J. Plant Physiol. 4(1): 899-905.

Rahmat, U. K., A. Rashid, M. S. Khan. and E. Ozturk. 2010. Impact of humic acid and chemical fertilizer application on growth and grain yield of rainfed wheat (*Truticum aestivum* L.). Pak. J. Agric. Res. 23(3-4): 113-121.

Sadra, S., G. R. Mohammadi. and F. Mondani. 2022. Effect of cover crops and application of nitrogen fertilizer on tuber yield and nitrogen use efficiency of potato (*Solanum tuberosum* L. cv. Sante). 24(3): 221-235.

Singh, D. K., A. K. Pandey, U. B. Pandey. and S. R. Bhonde. 2002. Effect of Farmyard Manure Combined with Foliar Application of NPK Mixture and Micronutrients on Growth, Yield and Quality of Onion. Newsletter-National Horticultural Research and Development Found. 21-22: 1-7.

Singh, D. P., N. S. Rana. and R. P. Singh. 2000. Growth and yield of winter maize (*Zea mays* L) as influenced by intercrops and nitrogen application. Indian. Agron. J. 45: 515-519.

Shafeek, M. R., Y. I. Helmy, M. Nadia. A. R. Omer. and Fatma. 2013. Effect of foliar fertilizer with nutritional compound and humic acid on growth and yield of broad bean plants under sandy soil conditions. J. Appl. Sci. Res. 9: 3674-3680.

Shevananda. A. 2008. Influence of biofertilizers on the availability of nutrients (N, P and K) in soil in relation to growth and yield of Stevia rebaudiana grown in South India. Int. J. Appl. Res. Natural Prod. 1: 20-24.

Soleimanzadeh, H. and F. Ghooshchi. 2013. Response of growth and yield of maize to bio-fertilizers in organic and conventional cropping systems. Intl. J. Agri. Crop Sci. 5 (7): 797-801.

Sujanya, S. and S. Chandra. 2011. Effect of part replacement of chemical fertilizers with organic and bio-organic agents in ground nut, *Arachis hypogeal*. J. Algal Biomass Utilization. 2(4): 38–41.

Tilak, K. V. B. R., C. S. Singh, N. K. Roy. and N. S. Subba Rao. 1992. Azospirillum brasilense and Azotobacter chrococcum inoculum effect on maize and sorghum. Soil Biol. Biochem. J. 14: 417-418.

Trevisan, S., D. Pizzeghello. and B. Ruperti. 2009. Humic substances induce lateral root formation and expression of the early auxin-responsive IAA19 gene and DR5 synthetic element in Arabidopsis. Plant Biol. J. 12: 604-614.

Turkmen, O., A. Dursun, M. Turan. and C. Erdinc. 2004. Calcium and humic acid affect seed germination, growth and nutrient content of tomato (*Lycopersicon esculentum* L.) seedlings under saline soil conditions. Acta Agric. Scandinavica Plant Soil Sci. J. 54: 168-174.

Venkatash-Warlu, B. 2008. Role of bio-fertilizers in organic farming: Organic farming in rain fed agriculture: Central institute for dry land agriculture. Hyderabad. Pakistan. pp: 85-95.

Vessey, J. K. 2003. Plant growth promoting rhizobacteria as biofertilizers. Plant Soil. J. 255: 571-586.

Waqas, M., B. Ahmad, M. Arif, F. Munsif, A. L. Khan, M. Amin, S. M. Kang, Y. H. Kim. and I. J. Lee. 2014. Evaluation of humic acid application methods for yield and yield components of mungbean. Am. J. Plant Sci. 5: 2269-2276. http://dx.doi.org/10.4236/ajps.2014.515241

Zhang, L., K. C. Loh, S. Sarvanantharajah, Y. Shen, Y. W. Tong, Ch. H. Wang. and Y. Dai. 2020. Recovery of Nitrogen and Phosphorus Nutrition from Anaerobic Digestate by Natural Superabsorbent Fiber-Based Adsorbent and Reusing as an Environmentally Friendly Slow-Release Fertilizer for Horticultural Plants. Waste Biomass Valor. 11: 5223–5237. https://doi.org/10.1007/s12649-019-00915-3.