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Effect of N Fertigation Rates and Humic Acid on The Productivity of Crisphead Lettuce (*Lactuca sativa* L.) Grown in Sandy Soil

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Abstract

Lettuce is a slow-growing plant, which often accumulates 70:80% of it is head biomass and N uptake just during the last three to five weeks before the harvest. As well, add humic acid (HA) with N fertilizers is helping reduce the loss of N via leaching, especially in sandy soil. Therefore, the doses of N fertilizer and HA preferably add them in harmony with the requirements of different lettuce growth stages. This investigation aimed to study effect of three N fertigation rates; 50, 100 and 150 kg ha^{-1} and four rates of humic acid (HA); control, 400, 800 and 1600 mg l^{-1} as well as their interaction on the growth, head characters and mineral uptake (N, P and K) of crisphead lettuce. The results showed that lettuce plants receiving N fertigation rate up to 150 kg ha^{-1} were achieved the highest fresh and dry weight of outer leaves and head as well as total yield ha^{-1}. Furthermore, the total chlorophyll content, T.S.S. and mineral uptake were improved with increase N fertigation rate up to 150 kg ha^{-1}. Crisphead lettuce plants that treated by 800 mg l^{-1} HA as drench gave the highest mean values of total yield per hectare (65.81 ton ha^{-1}), fresh and dry weight of outer leaves and head and N, P and K uptake as well as chlorophyll content and T.S.S. Whereas, the ratio of outer leaves: head as the dry weight base was a significant increase with an increase in HA rate up to 1600 mg l^{-1}. Generally, the results showed that lettuce plants receiving N fertigation up rate 150 kg ha^{-1} + 800 mg l^{-1} HA achieved the highest mean values of fresh and dry weight of outer leaves and head as well as total yield ha^{-1} and chlorophyll content of crisphead lettuce plants.

Keywords: fertigation, humic, growth, head characters, mineral uptake, total chlorophyll, T.S.S.

1. Introduction

Crisphead lettuce (*Lactuca sativa* L.) is a leafy crop belongs to the Asteraceae family (formerly *Compositae*). Lettuce is one of the best-selling salad vegetable crops, especially in dry regions, such as Saudi Arabia. Where, it is a moisturizer for the human body and gives a sense of satiety. Therefore, crisphead lettuce often used in fast food, quick serve restaurants and preparation the low-energy meals.

Fertilization through irrigation (fertigation) is one of the agricultural practices that contribute to the increase an efficient use of fertilizers and water.

Lettuce is a slow-growing plant that often accumulates 70:80% of it is head biomass and N uptake just during the last three to four weeks before the harvest (Gardener & Pew, 1979; L. T. Thomas & A. D. Thomas, 1995). Therefore, the doses of N fertilizer preferably added in harmony with the different lettuce growth stages. Whereas, must add small doses of the N fertilizer during the early growth stage, while the great doses of it added during the last month before the harvest of lettuce plants. On the other hand, in sandy soil, the most important problems facing the lettuce production under drip irrigation system is restricting the roots spread of crops and that concentrated only in the soil wetness zone, which requires to frequent supply of irrigation water and fertilizers (fertigation) for the plant root zone soil (Feleafel et al., 2014). Moreover, most N fertilizers used through the drip irrigation system are a high solubility and the crop uses about 50% of the amount applied and the rest lost by lixiviation in the soil, or volatilization into the atmosphere. Under these conditions, the adding of humic acid to lettuce plants that grown in sandy soil, maybe a viable option to increase the size root system, which reflects on increase use efficiency of nitrogen fertilizer.

Nitrogen is an essential element that plays an important role in growth and productivity lettuce (Schenk, of 1996). Application of N fertilizers increased vegetative growth characters of lettuce plants (Greenwood et al., 1991). The excessive use of nitrogen fertilizer above the optimal levels (120 to 200 kg ha^{-1}) led to a reduction in lettuce yield (Soundy & Smith, 1992) and resulted in low marketing quality and high loss of nutritional value (Schuphan, 1972; Hartrath, 1986). In addition, one of the problems that may arise from the super-optimal N supply is accumulate nitrate in the edible tissue (Custic et al., 1994). On the other hand, low levels of N results in small head size and poor yield (Burns, 1988).

Humic acid (HA) is very large and complex molecules extracted from organic matter have been used in many ways to vegetable crops; where it is added as a drench to root zone or as a foliar spray. HA plays a major role in soil cation exchange capacity, improve water holding capacity, pH buffering (McDonnell et al., 2001), and plant and root development (Nardi et al., 1996). Researchers clarified several positive effects of HA such as increasing cell membrane permeability (Sial et al., 2007), photosynthesis (Russo & Berlyn, 1990; Chen et al., 1994), root elongation (Bohme & Lue, 1997). HA increase growth and yields of various vegetable crops (Hayes & Wilson, 1997; Atiyeh et al., 2002; Zandonadi et al., 2007). Studies show that humic acid was in general not only beneficial to shoot and root growth, but also nutrient uptake of vegetable crops (Padem et al., 1997; Akinremi et al., 2000; Dursun et al., 2002; Cimrin & Yilmaz, 2005). Foliar spray of HA has promoted growth in a number of plant species (Brownell et al., 1987), as a result of increasing cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus uptake, and supplying root cell growth (Cacco & Dell Agnolla, 1984; Russo & Berlyn, 1990). Liu et al. (1998) reported that 400 mg l^{-1} HA enhanced photosynthetic rates of plants as compared to control.

The present study conducted to search the effect of the N fertigation rates added in graded doses corresponding to the growth stages of lettuce plants and their interaction with humic acid concentrations on the growth, head characters and nutrient uptake, under sandy soil.

2. Material and Methods

An experiment was conducted at the Agricultural Experiment Station, Hada-Alsham, King Abdulaziz University, Saudi Arabia, through the agricultural season of 2010/2011 to study the effect of the N fertigation rates and their interaction with humic acid concentrations on the growth, head characters and nutrient uptake.

2.1 Treatments

The trial consisted of 12 treatments comprising combinations of three N fertigation rates; 50, 100 and 150 kg ha^{-1} and four rates of humic acid (HA); control, 400, 800 and 1600 mg l^{-1}. The N fertigation rates added in graded doses corresponding to the growth stages of lettuce plants. The application of HA was executed four times one of them as a drench to the plant root area at rate 0.25 l per plant after transplanting and other doses were added at 20, 40, and 60 days after transplanting. The control plants were treated with tap water.

2.2 Soil and Irrigation Water Analyses

Before the start of the experiment, some important physical and chemical properties of the experimental site soil (0–30 cm) were estimated according to the published procedures by (AOAC, 1995). The soil texture is sandy loam -clay (59.6% sand, 20.3% silt and 20.1% clay) with pH = 7.6 and organic matter = 0.43%. EC of the soil was 3.2 dS m^{-1}. Available soil N, P and K were 29, 9 and 18 mg kg^{-1}, respectively. The irrigation water was obtained from a local well. The irrigation water had an EC value of 3.6 dS m^{-1} and contained Na = 24.1, Mg = 0.81, Ca = 7.22, HCO_3 = 0.59, Cl = 30.3 and SO_4 = 7.2 meq l^{-1}.

2.3 Experimental Design

The experimental design used was the split-plot system in a randomized complete blocks design with three replications. The N fertigation rates were, randomly, arranged in the main plots, while four rates of humic acid were, randomly, distributed in the sub-plots. Each sub-plot contained two rows having an area of 16 m^2.

Seedlings of lettuce (Paris Island Cos cv.) were transplanted into the field on November 20, 2011, in two lines on each row. The row spacing was 30 cm between the seedlings and 70 cm between the lines in a row. The rows were 8m length and 100 cm apart. Each experimental unit contained two rows having an about 100 plants.

2.4 Irrigation and Fertilization

The actual evapotranspiration of the lettuce crop (ETc), under Hada-Alsham region conditions, was calculated and adjusted at the beginning of each growth stage (Table 1) by multiplying reference evapotranspiration (ET_0) for different months of the growing season (November, 2011–February, 2012) by a crop coefficient (K_C), $ET_c = ET_0 \times K_C$, as indicated in Allen et al. (1998) and Basahi (2007). The drip irrigation system consisted of laterals

GR of 16 mm in diameter with drippers at 0.3 m distance. The drippers had a discharge rate 4 l h^{-1}. Irrigation water was applied through the drip irrigation system, every alternate day, to maintain soil moisture above 50% soil moisture depletion, according to Qassim and Ashcroft (2002), which is the optimum level of lettuce plants.

Table 1. Length of the growth stages, crop coefficients (Kc), reference evapotranspiration (ET0) and water requirements (ETc), during the growing season of lettuce crop (November, 2011 to February, 2012), at Hada-Alsham region conditions, Saudi Arabia

Growth stages	Initial	Development	Mid-season	Late
Number of days per stage	20	30	15	15
Crop Coefficients (KC)	0.4	0.65	1	0.95
Reference evapotranspiration (ET0) mm day^{-1}	4.1	5.6	6.4	6.8
Water requirements of lettuce crop (ETc) mm day^{-1}	1.64	3.64	6.4	6.46
Total water requirements per growth stage (301 mm total)	32.8	109.2	96	64.6

The schedule of the percentage of N fertigation rates (50, 100, 150 kg N, ha^{-1}) and fertigation frequency (three doses weekly = 33 doses $season^{-1}$) during the varied growth stages of lettuce plants are shown in Table 2. N fertilizers (urea and ammonium nitrate) were injected directly into the irrigation water (fertigation), using a venture injector, starting in the 2nd week after transplanting up to the 11th week. Where, urea was added during the first three weeks only (2-4 week), while ammonium nitrate was added throughout the eight subsequent weeks. The other fertilizers were used at the rates 450 kg ha^{-1} of calcium super-phosphate (16-18% P_2O_5), added to the soil before transplanting. Moreover, potassium sulfate (48% K_2O) at rate 200 kg ha^{-1}, was injected directly into the irrigation water, mixed with nitrogen fertilizers, at fixed doses (33 doses $season^{-1}$). All agricultural practices were done as commonly followed in the commercial production of lettuce in the drip irrigation system.

Table 2. Schedule of the percentage of N fertigation and fertigation frequency during the varied growth stages of lettuce plants

Treatments		Total doses	% and time of N addition			
			Initial	Development	Mid-season	Late
N Fertigation Rate (kg ha^{-1})	Fertigation Frequency		3WAT*	4WAT	2WAT	2WAT
50	3 doses weekly	33	1×9	2×12	4×6	7.1×6
100	3 doses weekly	33	1×9	2×12	4×6	7.1×6
150	3 doses weekly	33	1×9	2×12	4×6	7.1×6

Note. *WAT = Weeks after transplanting.

2.5 Data Recorded

Harvest crisphead lettuce plants were done 80 days after transplanting; all plants of each sub-plot were harvested and weighed then converted into total yield tons ha^{-1}. Ten plants were randomly selected from each experimental unit to measure and determinate the following traits: fresh and dry weight of lettuce plants. Outer leaves of previously plants were separated, and then the following data were recorded: total chlorophyll content, fresh and dry weight of the outer leaves $head^{-1}$ as well as fresh and dry mass of the head. T.S.S. of samples from heads was measured by hand Refractometer. Samples of dry outer leaves and head were digested using concentrated sulfuric acid and H_2O_2 and analyzed for N-P-K nutrients as described in Cottenie (1980). The uptake of N, P and K calculated as the product of the crop biomass (dry weight). The obtained values of N, P and K concentrations were multiplied with the dry matter content of lettuce plants; the N, P and K uptake ha^{-1} was derived based on lettuce plant population.

2.6 Statistical Analysis

All obtained data of the present study were statistically analyzed according to the design used by the MSTATC computer software program (Bricker, 1991). The comparisons among means of the different treatments were carried out by using the revised L.S.D. test.

3. Results

3.1 Effects on Crisphead Lettuce Plants Characters

Increasing N fertigation applied dose up to 150 kg ha^{-1} was associated with significant progressive increase in the fresh and dry weight of lettuce plants (Table 3). The same trend was detected in the values of fresh and dry mass of outer leaves and head of lettuce plants. Moreover, the result showed that increasing N fertigation rate up to 150 kg ha^{-1} lead to increase the outer leave:head ratio, whether as fresh or dry weight basis. Lettuce plants receiving N fertigation rate up to 150 kg ha^{-1} recorded maximum total yield ha^{-1} compared with the plants that treated with either 50 or 100 kg N ha^{-1}. The increase was about 45.5% at the higher N fertigation rate compared with the lower rate.

The fresh and dry weight of lettuce plants, outer leaves and head (Table 3) showed a significant increase with an increment of HA up to 800 mg l^{-1} compared to control treatment. However, the outer leave: head ratio as fresh or dry weight basis of lettuce plants was differed in its response to HA rates. Whereas, the percentage of outer leaves: head as dry weight base was significant increase with an increase in HA rate up to 1600 mg l^{-1} , while as fresh weight base not shown any significant response to increase the rate of humic (Table 3). Increasing the HA level up to 800 mg l^{-1} lead to a significant progressive increase in the total yield per hectare (65.81 ton ha^{-1}) of lettuce plants.

The interaction effects between N fertigation rates and HA application reflect significant response in all crisphead lettuce plants characters (Table 3). The data shown that at any N fertigation rate, successive increases in HA level up to 800 mg l^{-1} were associated with a corresponding and significant increases in the fresh and dry weight of lettuce plants, fresh and dry mass of outer leaves and head and outer leave:head ratio as well as total yield. The combined treatment, which included 150 kg N ha^{-1} + 800 mg l^{-1} HA can be considered the best treatment and it gave the highest values of all studied characters of crisphead lettuce plants. The increase in the total yield ha^{-1} of lettuce plants was about 121.9% compared with combined treatment, which included the lower rates of N and HA (50 kg N ha^{-1} + 0 mg l^{-1}HA).

Table 3. Effect of N fertigation rates and humic acid concentrations on the head characters of crisphead lettuce plants

Treatments		Fresh weight (g pl^{-1})			Dry weight (g pl^{-1})			Outer:Head (%)		Total Yield (ton ha^{-1})
N Fertigation Rates (kg ha^{-1})	Humic acid rates (mg l^{-1})	plant	Outer leaves	Head	Plant	Outer leaves	Head	Fresh	Dry	
50		759.27C*	121.67C	637.6C	105.9C	19.15C	86.75C	19.08B	22.07C	47.45C
100		887.01B	145.08B	741.93B	120.56B	25.50B	95.06B	19.55B	26.83B	55.44B
150		1104.51A	193.08A	911.43A	158.69A	37.59A	121.1A	21.18A	31.04A	69.03A
	0	765.43D	126.22D	639.21D	102.03D	21.15D	80.88D	19.75A	26.15B	47.84D
	400	883.66C	142.67C	740.99C	119.72C	24.66C	95.06C	19.25A	25.94B	55.23C
	800	1052.89A	183.22A	869.67A	155.94A	34.45A	121.49A	21.07A	28.36A	65.81A
	1600	965.77B	161.00B	804.77B	135.83B	29.39B	106.44B	20.01A	27.61A	60.36B
50	0	597.10k	104.67k	492.43l	85.71i	14.56i	71.15k	21.26ab	20.46g	37.32g
	400	751.44j	116.67j	634.77k	104.49g	17.43h	87.06i	18.38fg	20.02g	46.97 f
	800	843.10g	139.33f	703.77h	122.25e	24.83f	97.42ef	19.80cde	25.49e	52.69 e
	1600	815.43h	126.00h	689.43i	111.15f	19.76gh	91.39gh	18.28g	21.62f	50.96 ef
100	0	782.77i	121.00i	661.77j	97.61h	20.96g	76.65j	18.28g	27.35c	48.92 ef
	400	844.76g	134.33g	710.43g	114.42f	24.35f	90.07hi	18.91efg	27.03cd	52.80 e
	800	990.43d	172.33d	818.10d	144.5c	29.91d	114.59c	21.06abc	26.10de	61.90 cd
	1600	930.10e	152.67e	777.43e	125.71e	26.79ef	98.92e	19.64def	27.08cd	58.13 d
150	0	916.43f	153.00e	763.43f	122.77e	27.93de	94.84fg	20.04b-e	29.45b	57.28d
	400	1024.77c	177.00c	847.77c	140.25d	32.19c	108.06d	20.88a-d	29.79b	64.05c
	800	1325.10a	238.00a	1087.10a	201.08a	48.60a	152.48a	21.89a	31.87a	82.82a
	1600	1151.76b	204.33b	947.43b	170.65b	41.64b	129.01b	21.57a	32.28a	71.99b

Note. * Values having the same alphabetical letter in common do not significantly differ at $P < 0.05$.

3.2 Chemical Constituents of Crisphead Lettuce

3.2.1 Total Chlorophyll Content and T.S.S.

Data in Table 4 revealed that total chlorophyll content of lettuce outer leaves and total soluble solid (T.S.S.) were significantly increased by raising the N fertigation rates up to 150 kg ha^{-1}.

With respect of effect of HA on total chlorophyll content of outer leaves and T.S.S. of head lettuce, data in Table 4 showed a clear response, where there is significant increases in chlorophyll content and T.S.S. were proportional to increase HA rates up to 800 mg l^{-1}.

Concerning the interaction effects of N fertigation rates and HA levels, resulted in Table 4 indicated that, N fertigation rates at 150 kg $ha^{-1}$and soil application of HA at 800 mg l^{-1}, seemed to be the highest value of total chlorophyll content compared with all possible combinations tested. However, crisphead lettuce plants receiving N fertigation rate 150 kg ha^{-1} + 1600 mg l^{-1} of HA, gave the highest value T.S.S.

3.2.2 Mineral Uptake (N, P and K)

Increasing the N fertigation rates was associated with significantly increasing mineral uptake (N, P and K) of crisphead lettuce (Table 4). Where, the results indicated that mineral uptake of lettuce plants increased by applying 150 kg N ha^{-1} compared with using 50 or 100 kg N ha^{-1}.

Increasing the humic acid level up to 800 mg l^{-1} that was supplied as drench application lead to a significant progressive increasing in N, P and K uptake of lettuce plants over control (Table 4).

The comparisons, presented in Table 4, showed the presence of significant interaction effects, between N fertigation rates and HA concentrations, on the mineral uptake (N, P and K) of lettuce plants grown under sandy soil. Generally, it was detected that the highest mineral uptake of lettuce plants were obtained from the treatment combination involving the with the N fertigation at rate 150 Kg ha^{-1} + 800 mg l^{-1} of HA.

4. Discussion

Fertilization program design under drip irrigation system requires information about the crop growth pattern, its growth stages and the accumulate biomass stage as well as available nitrogen form and its doses. The fertilization through the drip irrigation water (fertigation) is one of the more agricultural practices that contribute to the increase an efficient use of fertilizers and water. On the other hand, the most important problems facing the lettuce production under drip irrigation system in sandy soil, is restricting the roots spread of crops and that concentrated only in the soil wetness zone (Feleafel et al., 2014). Moreover, lettuce is a slow-growing plant that often accumulates 70:80% of its head biomass and N uptake just during the last three to five weeks before the harvest (Gardener & Pew, 1979; L. T. Thomas & A. D., 1995). Therefore, in this study the thirty-three doses of N fertilizer were added in harmony with the different lettuce growth stages, where small doses of the N fertilizer were added during the early growth stage, while the great doses of N were added during the last three weeks before the harvest of lettuce plants.

The results indicated that lettuce plants receiving N fertigation rate up to 150 kg ha^{-1} were achieved maximum fresh and dry weight of outer leaves and head as well as total yield ha^{-1} of lettuce plants compared with the plants that treated with either 50 or 100 kg N ha^{-1}. Furthermore, the total chlorophyll content, T.S.S. and mineral uptake (N, P and K) were improved with increase N fertigation rate up to 150 kg ha^{-1}. These findings appeared to agree with the results reported by many researchers (Richard et al., 1985; Huett & Dettmann, 1992; Custic et al., 1994; EL-Araby & Feleafel, 2001). Mitchell et al. (1991) stated that leaf chlorophyll content of lettuce was increased by doubling N rates in the nutrient solution. Türkmen et al. (2004) found that nitrogen application significantly affected the head weight and nitrate, nitrogen, phosphorus, iron, manganese, copper and zinc contents. Boroujerdnia and Ansari (2007) showed that nitrogen status significantly influenced growth and yield attributes of lettuce. This effect may be explained based on the physiological fact; nitrogen is a part of chlorophyll and its importance in the metabolism of many constituents such as amino acids, chlolophyll, auxins enzymes and general protein synthesis (Thompson & Troeh, 1978; Marschner, 1995). Additionally, Squire et al. (1987) established that the main effect of N fertilizer was to increase the rate of leaf expansion, leading to increased interception of daily solar radiation by the outer leaves, which enhanced more of head leaves formation. In addition to the positive response of lettuce yield to N fertigation rate may be attributed to remobilization of N and K from outer leaves to head that occurred over the last week of the growth period for lettuce as reported by Huett and Dettmann (1992).

Table 4. Effect of N fertigation rates and humic acid concentrations on total chlorophyll content, T.S.S. and mineral uptake of crisphead lettuce plants

Treatments		Humic Acid rates ($mg\,l^{-1}$)	T.S.S.	Mineral uptake ($Kg\,ha^{-1}$)		
N Fertigation Rates ($kg\,ha^{-1}$)	Total Chlorophyll content ($mg\,g^{-1}$ dry weight)			N	P	K
50		5.29C*	7.23B	51.95C	34.61C	83.11C
100		5.88B	7.54B	77.34B	31.02B	108.65B
150		6.71A	7.97A	141.14A	37.99A	241.86A
	0	5.37D	7.24B	41.80D	31.52D	66.06D
	400	5.76C	7.50B	75.51C	35.06C	114.67C
	800	6.58A	7.84A	142.07A	37.22A	231.81A
	1600	6.15B	7.72A	100.31B	34.36B	165.62B
	0	4.85f	6.90e	21.25l	33.73de	37.42l
	400	5.69de	7.07de	54.64j	39.43b	63.09j
50	800	5.66de	7.53a-e	79.73f	32.95ef	146.28e
	1600	5.45ef	7.40a-e	58.71i	32.35f	85.67h
	0	5.29ef	7.10cde	40.51k	28.41i	54.19k
	400	5.82cde	7.50a-e	65.39h	30.23h	75.26i
100	800	6.44bc	7.87abc	121.51c	34.27d	189.27d
	1600	5.98cde	7.70a-d	93.52e	31.17g	115.88f
	0	5.96cde	7.73a-d	70.16g	32.43f	106.57g
	400	6.26cd	7.93ab	111.15d	35.54c	205.66c
150	800	7.63a	7.23b-e	249.32a	44.44a	359.89a
	1600	7.00ab	8.07a	161.92b	39.56b	295.32b

Note. * Values having the same alphabetical letter in common do not significantly differ at $P < 0.05$.

Crisphead lettuce plants that treated by 800 mg l^{-1} HA as drench showed significantly increased the fresh and dry weight of outer leaves and head and N, P and K uptake as well as chlorophyll content and T.S.S. Whereas, the ratio of outer leaves: head as dry weight base was significant increase with an increase in HA rate up to 1600 mg l^{-1}. Also, application of HA at rate 800 mg l^{-1} gave the highest mean values of total yield per hectare (65.81 ton ha^{-1}) of lettuce plants. These findings appeared to agree to the results reported by Türkmen et al. (2004), they found that HA application significantly affected the head weight, nitrogen, nitrate and phosphorus contents. This can be explained based on that, there were several hypotheses suggesting the formation of a complex between HA and mineral ions, their involvement in the enhancement of enzyme catalysis, their influence of stimulating respiration, photosynthesis and nucleic acid metabolism (Nardi et al., 1996). Furthermore, HA has hormone-like activity enhances plant growth and the nutrient uptake (El-Hefny, 2010; Kulikova et al., 2005). HA increasing plant growth enormously due to increase cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus uptake, and supplying root cell growth (Russo & Berlyn, 1990). In addition, Haghighi et al. (2012) stated that the photosynthetic activity of lettuce increased with 100, or 1000 mg l^{-1} levels of HA due to enhancement of chlorophyll content and mesophyll conductance.

Concerning the interaction effect of N fertigation rate and HA rate, the results showed that lettuce plants receiving N fertigation up rate 150 kg ha^{-1} + 800 mg l^{-1} HA had the highest mean values of fresh and dry weight of outer leaves and head as well as total yield ha-1 and chlorophyll content of crisphead lettuce plants. The positive effects of interaction between application of N fertigation rate and HA may be attributed to stimulate the photosynthesis process. Add humic acid with N fertilizers will be help reduce the loss of nitrogen via leaching and will lessen the impact on soil biology. Besides, soil application of HA remaining concentrated near the point of application, thus help in improved nutrient availability in the root zone, thus reflected this effect on increasing the vegetative growth and increase head lettuce yield. The obtained results confirmed the findings of Haghighi et al. (2012), they demonstrated that HA accelerated uptake of N and NO_3 and accelerated N metabolism by enhancing nitrate reductase activity, which resulted in production of protein. Moreover, HA may be able to stimulate N metabolism and photosynthesis activity of lettuce to improve yield.

5. Conclusion

It is concluded that the combination of nitrogen fertigation and humic acid have the potential to be used to increase the productivity of crisphead lettuce grown in sandy soil, as a low input to reduce the loss of nitrogen via leaching.

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