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OPTIMAL INTERACTIONS OF NITROGEN FERTILIZER RATES AND WATER LEVELS FOR HIGHEST PERFORMANCE OF GREENHOUSE LETTUCE IN KARLO KABETE, NAIROBI

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Abstract
An experiment was conducted at the KALRO Kabete situated in peri-urban Nairobi, laid out as a split plot in a randomized complete block design (RCBD) for two seasons (Season one Oct- Dec, 2017) and (Season two, Jan to Feb, 2018). The treatments included 3 levels of irrigation (W_1-100% (22 minutes), W_2-70% (17 minutes) and W_3-40% (12 minutes) to FC) in main plots while 4 Nitrogen levels (0, 65, 105, and 145kg N/ha) were assigned to the subplots, resulting in 12 treatment combinations which were replicated three times. Findings showed significant variation due to interaction effect of nitrogen fertilizer rates and water levels on lettuce height and number of leaves at season two but insignificant during season one. Significant variation was observed due to the interaction effect of nitrogen fertilizer rates and water levels on lettuce diameter at season one and season two. There was significant variation observed due to interaction effect of nitrogen fertilizer rates and water levels on percentage chlorophyll during both seasons. However, no significant variation was observed due to interaction effect of nitrogen fertilizer rates and water levels on fresh and dry weight of lettuce during season one and season two. As such, farmers growing lettuce under greenhouse technology should use the 40% to Field Capacity with 65kg N/ha combination of irrigation water that is applied for 12 minutes (160mls/12 min/plant/day) at 40% to the field capacity and nitrogen fertilizer in a split-application rate of 65kg N/ha (4g/plant/split) since it exhibited efficient resources use.

Key words: N fertilizer rates, water levels, lettuce, KARLO Kabete, Nairobi

I. Introduction

Sub-Saharan Africa (SSA) is still grappling with food security caused by many factors including nutrient mining in which most nutrients are harvested with the crops but are not replenished back

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into the soil (Tully *et al.,* 2015). Lettuce crop currently receives a keen interest in the whole world due to its economic value and is a popular accompaniment of major meals (Hasan *et al.,* 2017). However, balanced application of nutrients and irrigation water, a pre-requisite for optimum production of any greenhouse crop (Jaria, 2012) remains a challenge for smallholder farmers in peri-urban areas in Kenya.

Lettuce is a leafy crop whose vegetative flourishment depends greatly on nitrogen nutrition. Application of water and nitrogen levels beyond the crop requirement has led to diverse crop problems culminating in massive lettuce crop failures and reduced yields (Kaiser & Ernst, 2016). Wise use of water and nutrients is very critical for the sustainability of crop production and for the future of irrigated agriculture (Gonzalez-Dugo *et al.,* 2010; Mancosu *et al.,* 2015). Scheduling water application is very crucial, as excessive or inadequate irrigations reduce yield, while inadequate irrigation and nutrients also causes water stress and poor yields. Water is an indispensable element for plants, affecting most physiological processes involved in growth and productivity (Mancosu *et al*., 2015). Further, UN Report (2013) indicated that water shortage and unbalanced nutrient application is one of the most common factors of stress that affects and limits agricultural productivity at world level. Crop responses to different rates of applied water matched with optimal nutrient recommendations have been used to determine irrigation strategies for optimal yield and maximum efficiency of water use (Badr, *et al*., 2012; Jones *et al.,* 2015)

According to Gonzalez-Dugo *et al.* (2010), lettuce is one of the crops most susceptible to water deficit and inadequate nitrogen and studies by Liu *et al.* (2014) have shown that this crop is highly dependent on water and nitrogen at all developmental stages, both for germination and to maintain high photosynthetic rates and a fresh biomass of high commercial value. In lettuce, where the harvested part of the plant is the photosynthetic leaf area, it is especially important to maintain optimal growth through the application of water and nitrogen (Alkhader & Rayyan, 2013, Batista *et al.,* 2013). Management practices that sustain lettuce production and improve soil and water quality are needed.

A balanced irrigation management and fertilizer application especially N are critical techniques that most small scale farmers get wrong (Luvai *et al.,* 2014). Further, farmers find it difficult to balance between the amounts of water to apply with the corresponding N, resulting in

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inefficiencies in both water and N fertilizer use. Thus, there is no sufficient information on studies carried out with lettuce crop in peri-urban towns in Kenya on yield response to applied irrigation water, optimum N amount and water use efficiency under greenhouse conditions.

Currently, however, lettuce production in Nairobi peri-urban systems is constrained by an over-application of nitrogen and water resources for purposes of optimal growth and yield performance (Njoroge & Obiero, 2014; Kamau, 2013). In most instances, water applied does not correspond to the nitrogen amounts that are optimally needed in greenhouse systems and the problem is worse for open field crops where soil moisture deficit is exacerbated unpredictable rainfall (Njoroge & Obiero, 2014). Wichelns (2015) argued that optimizing water use efficiency for any given crop will be very critical in achieving both food and water security to meet the demands of the ever increasing world's population. Mongare and Chege, (2011) opines that minimizing water loss through adoption of the best irrigation practices based on the plant's irrigation requirement and optimizing costs through optimal nitrogen application is a prerequisite to sustainable production of lettuce in Nairobi peri-urban. Therefore matching nitrogen requirement for lettuce and applied irrigation water would optimize these requirements for increased lettuce crop yields.

II. Materials and methods

The study was conducted at the National Agricultural Research Laboratories, KALRO in Westlands sub-county, Nairobi. It lies between latitude 1° 16' 5.751"N and 1° 16' 5.751"S and longitude 36° 48' 40.037"E and 36° 48' 40.037"E. Lettuce variety, Great Lakes were used in the experiment. The experimental design used was a factorial on a split plot arrangement as a randomized complete block design (RCBD) with three replicate block in a (3x4x3) factorial arrangement (Figure 3.2). A sub-plot measured 1mx2m accommodating 12 plants. The crop was spaced at 60cm (inter row) x 20cm (interplant). The main plot measured 4m by 2m accommodating 48 lettuce plants. There were three blocks each measuring 8 m by 6 m and consisting of 144 plants. The whole experimental unit had 432 plants with a germination of 97%. Irrigation management at 40%, 70% and 100% to FC moisture content that worked out to 300 mls for 22minutes for water level 1 (W1), 230 mls for 17 minutes for water level 2 (W2) and 160 mls for 12 minutes for water level 3 (W3) per plant per day were assigned to the main plots. N-fertilizer applied at 4 levels comprised the sub-plots and were combined to give a total of 12 treatment interactions. The experiment was composed of a total of 36 plots; three water levels,

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four N levels replicated three times. Data collected on plant height, diameter, number of leaves, chlorophyll, fresh and dry weight were subjected to analysis of variance (ANOVA) using GenStat version 15. Separation of means was performed using Turkey's test. ANOVA was used to determine whether there were any statistically significant differences between the treatments means while Turkey's test was used because the test procedure accurately maintains the alpha levels at 0.05.

III. Results and discussion

3.1 Plant height

The tallest plants (23.4, 23.4 and 23.2 cm) were recorded at W_2N_2, W_2N_0 and W_1N_2 respectively during season one. This was caused by adequate dissolution of the nutrients at higher water levels whose root tension to exerted by the roots is minimal. During season two, tallest plants were 20.1, 19.62, 19.6 cm at W_1N_0, W_2N_0 and W_1N_2 respectively. The shortest plants (18.9, 18.5 and 17.1 cm) were recorded at W_3N_0, W_2N_1 and W_1N_3 respectively during season two (Table 1). Comparing the height of the lettuce plants with the control, W_3N_0, (21.9cm and 17.22 cm), results showed that all the treatments had taller plants except for treatments W_1N_3, W_3N_3 and W_2N_2 during season one which had 21.7, 21.2 and 21.2 cm long. This was due to the interference of the physiological processes in the plant due to application of above N recommended rates.

Table 1: Optimal interactions of N fertilizer rates and water levels on plant height

	Plant height	
Treatments	**Season one**	**Season two**
W_1N_0	22.5	20.1^{a}
W_1N_1	22.6	19.51^{ab}
W_1N_2	23.2	19.6^{ab}
W_1N_3	21.7	18.85^{ab}
W_2N_0	23.4	19.62^{ab}
W_2N_1	22.9	18.51^{bc}
W_2N_2	23.4	19.36^{ab}
W_2N_3	21.2	19.24^{ab}
W_3N_0	21.9	17.22^{c}
W_3N_1	22.0	19.01^{ab}
W_3N_2	22.0	19.14^{ab}
W_3N_3	21.2	19.17^{ab}
	p values of significance test	

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Water	0.008*	0.203
Nitrogen	0.049*	0.691
W*N	0.459^{ns}	0.004***

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at *P* = 0.05

Where;

-W_1N_0=100% to Field Capacity with 0kg N/ha
-W_1N_1=100% to Field Capacity with 65kg N/ha
-W_1N_2=100% to Field Capacity with 105kg N/ha
-W_1N_3=100% to Field Capacity with 145kg N/ha
-W_2N_0=70% to Field Capacity with 0kg N/ha
-W_2N_1=70% to Field Capacity with 65kg N/ha
-W_2N_2=70% to Field Capacity with 105kg N/ha
-W_2N_3=70% to Field Capacity with 145kg N/ha
-W_3N_0=40% to Field Capacity with 0kg N/ha
-W_3N_1=40% to Field Capacity with 65kg N/ha
-W_3N_2=40% to Field Capacity with 105kg N/ha
-W_3N_3=40% to Field Capacity with 145kg N/ha
-W*N = Interaction of water and nitrogen

Significant variation (0.004***) was observed due to interaction effect of nitrogen fertilizer and water on lettuce height at season two but the heights were insignificant during season one. These findings showed that higher amounts of water application resulted into increased plant height. Similarly, where little water was applied, lowest plant height was observed at the later developmental growth stages of the lettuce crop. Findings showed that as application of nitrogen was increased, an increase in plant height was observed but up to a limit of 105Kg N/ha. More nitrogen application showed resulted to lowest plant height at the later growth stages. Nitrogen fertilizer was important as it ensured a conducive environment for elongation of lettuce plant with optimum vegetative growth. Generally, the height of lettuce crop was shorter during season two under the effect of both water and nitrogen.

Bozkurt and Gulsum (2011) found that moisture levels had significantly ($p < 0.01$) different effects on plant height of lettuce under greenhouse conditions. The findings of this study are similar to those of Acar *et al.* (2008) who did not find significant differences in terms of plant height, between different N amounts. Similarly, Bozkurt *et al.* (2009) found that different N amounts did not have any effect on lettuce plant height. In another study by Yeshiwas (2017), results indicated that nitrogen fertilizer did not have significant effect on plant height. In contrast, Farag *et al.* (2013) obtained results that indicated that the increasing nitrogen level up to 150 ppm significantly increased plant height of lettuce grown in coconut fiber in Egypt.

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3.2 Plant diameter

The longest lettuce diameter (42.64, 42.14 and 42.08 cm) was found from W_2N_2, W_1N_2 and W_1N_0 respectively during the first season. The shortest lettuce diameter (37.81 and 38.15 cm) was obtained from W_3N_2 and W_1N_3 respectively during the season one. 31.42 cm and 30.13 cm were the longest plants in diameter during season two for W_1N_1 and W_1N_0 treatments. W_1N_3, W3N2 and W_3N_3 treatments had shorter diameter compared to the control during season one. All the lettuce plants had longer diameters during season two in respect to the control which was 22.1 cm long (Table 2).

Table 2: Optimal interactions of N fertilizer rates and water levels on plant diameter

	Plant diameter	
Treatments	**Season one**	**Season two**
W_1N_0	42.08^{a}	30.13^{ab}
W_1N_1	40.7^{ab}	31.42^{a}
W_1N_2	42.11^{a}	29.17^{abc}
W_1N_3	38.15^{c}	28.15^{abc}
W_2N_0	41.22^{a}	27.23^{bc}
W_2N_1	41.96^{a}	27.82^{bc}
W_2N_2	42.64^{a}	27.75bc
W_2N_3	42.31^{a}	25.99^{c}
W_3N_0	40.71^{ab}	22.1^{d}
W_3N_1	40.78^{ab}	27.77^{bc}
W_3N_2	37.81$_{c}$	28.33^{abc}
W_3N_3	38.42^{ab}	27.77^{bc}
	p values of significance test	
Water	0.012*	0.017*
Nitrogen	0.047*	0.03*
W*N	0.004**	0.008**

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at $P = 0.05$

Where;

-W_1N_0=100% to Field Capacity with 0kg N/ha
-W_1N_1=100% to Field Capacity with 65kg N/ha
-W_1N_2=100% to Field Capacity with 105kg N/ha
-W_1N_3=100% to Field Capacity with 145kg N/ha
-W_2N_0=70% to Field Capacity with 0kg N/ha
-W_2N_1=70% to Field Capacity with 65kg N/ha
-W_2N_2=70% to Field Capacity with 105kg N/ha
-W_2N_3=70% to Field Capacity with 145kg N/ha
-W_3N_0=40% to Field Capacity with 0kg N/ha
-W_3N_1=40% to Field Capacity with 65kg N/ha
-W_3N_2=40% to Field Capacity with 105kg N/ha
-W_3N_3=40% to Field Capacity with 145kg N/ha
-W*N = Interaction of water and nitrogen

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Significant variation was observed (0.004** and 0.008** at season one and season two respectively) due to interaction effect of nitrogen fertilizer and water on lettuce diameter (Table 4.3). This showed that with higher amounts of water application, increased plant diameter was observed, where little water was applied, lowest plant diameter was observed at the later developmental growth stages of the lettuce crop indicating the need for water for the lettuce crop phenological stages.

The findings agree with those of Kizil *et al.* (2012) who found a significant difference in plant diameter of lettuce under varying moisture levels. Additionally, Ustun*et al.* (2016) found out that the effect of different irrigation quantities on lettuce plant diameter was significant. Further, significant reduction in plant diameter was observed across the different moisture levels in the production of greenhouse tomatoes (Luvai, 2014). Hamdi *et al.* (2014) also indicated that different nitrogen fertilizer levels significantly affected lettuce plant diameter. The results of this study contrasts those of Nina and Osvald (2002) who found that different nitrogen levels did not have significant effect on lettuce plant diameter.

3.3 Number of leaves

Maximum number of leaves (12.1, 12.0 and 11.9) was found fromW_2N_1, W_3N_0 and W_1N_0 respectively during season. Minimum number of leaves (8.8, 9.2 and 9.3) was found from W_3N_0, W_2N_1 and W_2N_0 respectively during season two. 12.0 and 22.1 were the number of leaves for the control (W_3N_0) during season one and two respectively which was the high compared to the other treatments in season one but the lowest in season two (Table 3).

Table 3: Optimal interactions of N fertilizer rates and water levels on number of leaves

	Number of leaves	
Treatments	**Season one**	**Season two**
W_1N_0	11.9	10.369^{a}
W_1N_1	11.5	9.833^{ab}
W_1N_2	11.0	9.738^{ab}
W_1N_3	10.9	10.452^{a}
W_2N_0	11.2	9.333^{b}
W_2N_1	12.1	9.19^{bc}
W_2N_2	11.6	10.179^{ab}
W_2N_3	11.4	9.607^{ab}
W_3N_0	12.0	8.298^{c}

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W_3N_1	11.6	9.333^{b}
W_3N_2	10.2	10^{ab}
W_3N_3	11.2	9.774^{ab}
	p values of significance test	
Water	0.085	0.155
Nitrogen	0.036^{*}	0.007^{**}
W*N	0.055^{ns}	0.002^{**}

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at *P* = 0.05

Where;

-W_1N_0=100% to Field Capacity with 0kg N/ha
-W_1N_1=100% to Field Capacity with 65kg N/ha
-W_1N_2=100% to Field Capacity with 105kg N/ha
-W_1N_3=100% to Field Capacity with 145kg N/ha
-W_2N_0=70% to Field Capacity with 0kg N/ha
-W_2N_1=70% to Field Capacity with 65kg N/ha
-W_2N_2=70% to Field Capacity with 105kg N/ha
-W_2N_3=70% to Field Capacity with 145kg N/ha
-W_3N_0=40% to Field Capacity with 0kg N/ha
-W_3N_1=40% to Field Capacity with 65kg N/ha
-W_3N_2=40% to Field Capacity with 105kg N/ha
-W_3N_3=40% to Field Capacity with 145kg N/ha
-W*N = Interaction of water and nitrogen

There was no significant variation observed due to interaction effect of the nitrogen fertilizer and water on number of leaves of lettuce at season one, however, it was significant at season two. The findings revealed that water was a significant factor in the number of leaves in lettuce crop. Maximum number of leaves was obtained when high amount of water was applied while the number of leaves was low with little water application. Findings showed the significance of N in lettuce growth yet cautioned on application of high amounts.

The results of this study are similar to those of Santosh *et al.* (2017) who found that the number of leaves of lettuce was not significantly affected by different irrigation water levels. Further, a study conducted by Karam *et al.* (2012) on nitrogen recovery of lettuce under different irrigation regimes indicated that different moisture levels caused by the deficit irrigations significantly reduced leaf number ($p<0.05$). In contrast, Mandefro and Kokobe (2015) results from variance analysis revealed that the number of leaves was significantly affected by different moisture levels in the production of lettuce in Southern Ethiopia. The results of this study contrasted with those of Hasan *et al.* (2017) who found significant variation for number of leaves/plant of lettuce with application of different levels of nitrogen. Boroujerdnia and Ansari (2007) also found that different levels of fertilizer on leaf number was significant at P<0.01. Further, Engelbrecht *et al.*

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(2010) found that different nitrogen levels significantly increased the number of leaves harvested in the production of Swiss Chard. Gyanendra *et al.* (2013) also indicated that application of different levels of nitrogen had a significant influence on leaf numbers of spinach beat.

3.4 Chlorophyll

Highest percentage chlorophyll (36.42, 36.04 and 35.45) was obtained fromW_1N_2, W_3N_0 and W_2N_3 respectively while lowest percentage chlorophyll (29.49, 29.98 and 30.51) was obtained fromW_2N_1, W_1N_0 and W_3N_3 respectively during both seasons. Percent chlorophyll for the control was high comparing the value with most treatments especially during season one (Table 4).

Table 4: Optimal interactions of N fertilizer rates and water levels on % chlorophyll

	Percentage chlorophyll	
Treatments	**Season one**	**Season two**
W_1N_0	33.62^{bc}	29.98^{de}
W_1N_1	34.01^{bc}	31.64^{abcd}
W_1N_2	36.42^{a}	31.61^{bcd}
W_1N_3	33.03^{c}	33.75^{a}
W_2N_0	33.44^{c}	29.49^{e}
W_2N_1	34.62^{abc}	30.74^{cde}
W_2N_2	35.39^{ab}	30.87^{cde}
W_2N_3	35.45^{ab}	33.18^{ab}
W_3N_0	36.04^{a}	31.11^{bcde}
W_3N_1	34.9^{abc}	33.11^{ab}
W_3N_2	34.77^{abc}	32.45^{abc}
W_3N_3	34.55^{abc}	30.51^{cde}
	p values of significance test	
Water	0.394	0.568
Nitrogen	0.07	0.001***
W*N	0.005**	0.003**

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at $P = 0.05$

Where;

-W_1N_0=100% to Field Capacity with 0kg N/ha
-W_1N_1=100% to Field Capacity with 65kg N/ha
-W_1N_2=100% to Field Capacity with 105kg N/ha
-W_1N_3=100% to Field Capacity with 145kg N/ha
-W_2N_0=70% to Field Capacity with 0kg N/ha
-W_2N_1=70% to Field Capacity with 65kg N/ha
-W_2N_2=70% to Field Capacity with 105kg N/ha
-W_2N_3=70% to Field Capacity with 145kg N/ha
-W_3N_0=40% to Field Capacity with 0kg N/ha
-W_3N_1=40% to Field Capacity with 65kg N/ha
-W_3N_2=40% to Field Capacity with 105kg N/ha
-W_3N_3=40% to Field Capacity with 145kg N/ha
-W*N = Interaction of water and nitrogen

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There was significant variation (0.005** and 0.003** during season one and season two respectively) observed due to interaction effect of nitrogen fertilizer and water on percentage chlorophyll. The findings showed the significance of N in the formation of the green colouring matter but it is worth noting that the percentage chlorophyll was lower during the latter growth stages during season two compared to season one.

Chlorophyll has been found to play an important role as primary photosynthetic pigment to capture light energy from the sun in all living plants. The colour is extremely important because it defines the appearance of the vegetables like lettuce (Qihua, 2011). Findings of this study showed that chlorophyll was significantly affected by the N application rates and the irrigation water levels.

3.5 Fresh and Dry Weight

Results showing fresh and dry weight are shown in Table 5. Highest fresh weight (15333, 15167 and 14333 kg/ha) was obtained from W_3N_1, W_2N_2 and W_2N_0 respectively during season one. Lowest fresh weight (8333, 10000 and 10167kg/ha) was obtained from W_3N_0 and W_3N_3 respectively. Control treatment had 8333 kg/ha at season two which was the lowest. Highest dry weight (1250, 1215 and 1167 kg/ha) was found fromW_2N_2, $W_3N_1$and W_2N_0 respectively. Lowest dry weight (547, 547 and 645kg/ha) was obtained from W_3N_3, W_3N_0 and W_2N_1 respectively. Control treatment had the lowest dry weight at season two. Findings showed that W_3N_1 (40% FC, 65kg N/ha) had the highest fresh and dry weight interaction effect of nitrogen fertilizer and water.

Table 5: Optimal interactions of N fertilizer rates and water levels on fresh and dry weight

	Fresh weight		Dry weight	
Treatments	**Season one**	**Season two**	**Season one**	**Season two**
W_1N_0	13667	11333	867	1167
W_1N_1	12167	13000	860	950
W_1N_2	11667	12333	877	825
W_1N_3	11500	12667	1025	1033
W_2N_0	14333	10667	1018	700
W_2N_1	13333	12833	648	1200
W_2N_2	15167	13333	1215	1117
W_2N_3	14000	13167	645	1165
W_3N_0	13333	8333	740	547
W_3N_1	15333	13677	1142	1250
W_3N_2	12000	11000	1017	700

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W_3N_3	10000	10167	547	922
p values of significance test				
Water	0.305	0.335	0.11	0.392
Nitrogen	0.714	0.095	0.684	0.671
W*N	0.966	0.212	0.301	0.130

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at $P = 0.05$

Where;

-W_1N_0=100% to Field Capacity with 0kg N/ha
-W_1N_1=100% to Field Capacity with 65kg N/ha
-W_1N_2=100% to Field Capacity with 105kg N/ha
-W_1N_3=100% to Field Capacity with 145kg N/ha
-W_2N_0=70% to Field Capacity with 0kg N/ha
-W_2N_1=70% to Field Capacity with 65kg N/ha
-W_2N_2=70% to Field Capacity with 105kg N/ha
-W_2N_3=70% to Field Capacity with 145kg N/ha
-W_3N_0=40% to Field Capacity with 0kg N/ha
-W_3N_1=40% to Field Capacity with 65kg N/ha
-W_3N_2=40% to Field Capacity with 105kg N/ha
-W_3N_3=40% to Field Capacity with 145kg N/ha
-W*N = Interaction of water and nitrogen

No significant variation was observed due to interaction effect of nitrogen fertilizer and water on fresh and dry weight of lettuce during season one and season two. The findings showed that with the increase of nitrogen application up to 105kg N/ha and water application to 70% field capacity, fresh and dry weight increased due to optimum vegetative growth and sufficient water supply. Application of N at 145kg N/ha reduced lettuce growth and the ultimate results were the low fresh and dry weight.

Studies carried out have shown that water in plants is required to permit vital processes such as nutrient uptake, photosynthesis and respiration (Kizil *et al.,* 2012). The findings of this study support those of Kizil *et al.* (2012) who indicated that decrease in irrigation water resulted in reduction in lettuce yield. Further, studies by Senyigit and Kaplan (2013) showed that the lettuce plant grown under green-house conditions at the region of Isparta and irrigated by drip irrigation method was very sensitive to water deficiency and it cannot be grown under greenhouse conditions without irrigation.

The results obtained by Tittonell *et al.* (2003), Rincon *et al.* (1998) and Boroujerdnia and Ansari (2007) were in contrast with the present study as they found significant effect of different N amounts. Further, a study by Bozkurt *et al.* (2009), found out that yield and other yield components were not affected by different N amounts. Nitrogen is one of the most important

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mineral nutrients determining plant growth. Its effects are associated with leaf area growth and photosynthetic rate (Pons & Westbeek, 2004). High nitrogen levels have been found to increase significantly vegetative growth of lettuce (Farag *et al.,* 2013). Severe water deficits of N have been found to reduce photosynthesis by non-stomatal mechanisms leading to decreases in the chlorophyll (Chaves & Oliveira, 2004; Lawlor & Tezara, 2009) thus low yields. Under greenhouse conditions, humidity, sunshine, wind, runoff and temperature are controlled. In this study, W3N1 giving significantly high yields indicate that there was efficient utilization of water and that the N applied sufficiently supplied the required nutrients.

Conclusion and recommendations

The study concluded that the optimal interaction of nitrogen fertilizer rates and water levels for highest performance of greenhouse lettuce was 40% to Field Capacity with 65kg N/ha and that the interactions were significant during season two. The study therefore recommended that farmers growing lettuce under greenhouse technology should use the 40% to Field Capacity with 65kg N/ha combination of irrigation water that is applied for 12 minutes (160mls/12 min/plant/day) at 40% to the field capacity and nitrogen fertilizer in a split- application rate of 65kg N/ha (4g/plant/split) since it exhibited efficient resources use.

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