Efficiency of Ammonium and Nitrate Ratios on Macronutrient Content and Morphological Properties of *Gerbera jamesonii* Cut Flower

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Summary

This experiment was carried out to study on the effect of different $NO_3^-:NH_4^+$ ratios on macronutrient content and growth of two cut gerbera (*Gerbera jamesonii* Bolus ex Hooker f.) cultivars in an open hydroponic system. The plants were nourished with different $NO_3^-:NH_4^+$ ratios as 100:0, 80:20, 60:40, and 40:60. The application of NO_3- and NH_4^+ at ratio 40:60 caused a reduction in flower height, stem and disk diameter, number of flowers, inflorescence fresh and dry weight, and vase life. Results indicated that N, P and NH_4^+ concentrations were enhanced in leaves of gerbera cultivars by increase of NH_4^+ ratio, whereas K, Ca, Mg, and nitrate were decreased. As compared to 'Double Dutch', the 'Stanza' cultivar could uptake more of N, P, and Mg. Inversely, 'Double Dutch' was able to uptake more of K and Ca than 'Stanza'. Defined optimal ratio of $NO_3^-:NH_4^+$ 80:20 could be used for gerbera production in vegetative and reproductive stages.

Key words

gerbera, ammonium, nitrate, nutrition, uptake

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Introduction

Gerbera (*Gerbera jamesonii* Bolus ex Hooker f.), commonly known as Transvaal daisy or Barberton daisy, is a member of the Asteraceae family that has 40 species scattered from Africa to Madagascar, tropical Asia and South America. Gerbera is especially known for their wide spectrum of colors and shapes, so its popularity has been increased worldwide (Jia et al., 2015). Gerbera is one of four the most popular cut-flowers in the world, as famous as roses, chrysanthemums, tulips, and lilies (Jia et al., 2015).

Soilless culture is a kind of modern plant cultivation system that uses different substrate (either inert organic or inorganic) through nutrient solution nourishment (Asaduzzaman et al., 2015). It is the most intensive culture system that utilizes all the resources efficiently for optimum yield of crops and the most intense form of horticultural enterprises for commercial production in greenhouse. In order to develop and promote the quality and yield of the cut flower of gerbera and enhance the total value, many studies have been conducted on the subject of soilless cultivation of gerbera (Chen et al., 2009).

Nutrient availability is one of the major factors influencing the suitability of soilless culture systems for growing ornamental plants. Horticultural and ornamental plants growth and quality depend largely on proper mineral nutrition. Nitrogen (N) is the pivotal mineral nutrient necessary in higher quantities and its accessibility is important factor for growth and quality of plants (Marschner and Rimmington, 1988). Approximately, 70–80 % of the total cation and anion uptake by plants is considered to result from the uptake of NH_4^+ - N or NO_3^- - N (Dickson et al., 2016). Either ammonium (NH_4^+) or nitrate (NO_3^-) as N sources can be used by plants (Roosta, 2014). The N source supplied to the plant affects growth and morphological development, as well as numerous physiological processes such as photosynthesis, root respiration, water relations, and secondary metabolism (Wang and Below, 1996).

The form of N supplied to the plant has a strong and inverse effect on uptake of cations or anions and pH regulation in the cytoplasm (Bernstein et al., 2005; Kiferle et al., 2013). Inappropriate NH_4^+:NO_3^- ratio results in phytotoxicity and impairs the product quality and quantity (Latigui et al., 2011; Mendoza-Villarreal et al., 2015). In all, increasing NO_3^- in fertilizer solutions stimulates organic anion synthesis and cation accumulation by the plant (Kraus et al., 2002).

In contrast, NH_4^+ often suppresses the absorption of cations and synthesis of organic anions produced by plants, whereas inorganic anion accumulation (SO_4^{2-}, PO_4^{3-}, and Cl^-) is increased (Kraus et al., 2002). At high external NH4+ concentrations, the uptake of N predominately in a cationic form suppresses the total anion uptake and this is balanced by excessive H^+ release from the root cells (Savvas et al., 2003). Therefore, it is feasible to acidify the growing medium pH. Conversely, the uptake of NO_3^- increases the growing medium solution pH because it takes place through a proton (H^+)/NO_3^- co-transport (Roosta, 2014). This situation can be improved by regulating the NH_4^+:NO_3^- ratio of the total N supplied through the nutrient solution. This ratio can serve as the main tool to balance the total cation to anion uptake ratio and maintain the pH within the desired range (Latigui et al., 2011).

The ornamental quality can be influenced by the NH_4^+/NO_3^- ratio (Ramos et al., 2013). Forms and levels of N can influence the postharvest behavior of potted plants. Symptoms of senescence observed on different organs during the storage period was more pronounced in the case of high N and ammonium supply as compared to greater proportions of nitrate (Druge, 2000). When the rate of NO_3^- was decreased, N content increased and phosphorus (P), magnesium (Mg), calcium (Ca), and potassium (K) in leaves decreased (Ismail and Othman, 1995).

When the proportion of NH_4^+ was increased to a 1:3 of total N, *Anthorium andreanum* showed a better growth, development and flowering (Dufour and Guérin, 2005). Plants exhibited a decrease in leaf K concentration and a decrease in leaf Ca as the proportion of NH4+ increased (Mendoza-Villarreal et al., 2015). In *Cotoneaster frigidus* leaves and roots, Ca, P, and Mg increased by reduction in NH_4^+:NO_3^- ratio in nutrient solution while in *Rudbeckia* by increasing NH_4^+ proportion, Ca and Mg in leaves increased whereas P, total N, and K decreased (Kraus et al., 2002).

Because the NH_4^+:NO_3^- ratio during fertilization affects the rhizosphere pH and nutrient uptake as mentioned above, the best ratio of the two N sources should be determined for the cultivation of the gerbera cut flower. Thus, our purpose was to evaluate the effects of two different N forms, NH_4^+ and NO_3^- at various ratios on growth, yield, and internal macronutrient changes in two gerbera cultivars.

Materials and methods

This experiment was carried out as completely randomized design (CRD) with eight treatments and three replications for study on the effect of different NO_3^-:NH_4^+ ratios on macronutrient partitioning of two cut gerbera (*Gerbera jamesonii*) in a hydroponic open system. Ten healthy tissue culture gerbera plantlets were taken as treatment unit. Gerbera plants, cv. red 'Stanza' and yellow 'Double Dutch' were planted in 3-L pots filled with perlite (0.2 - 5.0 mm) and grown in a greenhouse. Greenhouse conditions were controlled (light intensity 150 μmol m^{-2} s^{-1}, day/night, 25/15±3°C; Relative humidity, 50 - 70%). A drip irrigation system in an open soilless culture system was used in this experiment. The plants were nourished with one of the following NO_3^-:NH_4^+ ratios: 100:0, 80:20, 60:40, and 40:60. According to our previous experiment, the best nutrient solution was selected and used to prepare the nutrient solution (the data have not been published yet). The compositions of the nutrients in the solutions were as follows: 1.25 P, 5.5 K, 3.0 Ca, 1.0 Mg, and 1.25 SO_4, (in mM); 30 B, 0.75 Cu, 5.0 Mn, 4.0 Zn, 35.0 Fe (Fe-EDTA), and 0.5Mo (in μM). Total nitrogen at 11.25 mM was provided as NO_3^- and NH_4^+ to give NO_3^-: NH_4^+ ratios of 100:0, 80:20, 60:40, and 40:60 (Table 1). The initial pH of the nutrient solutions containing nitrate and ammonium nitrogen was adjusted to 5.5 - 5.8 by adding 1M H_2SO_4 or NaOH. The electrical conductivity (EC) of the nutrient solution was within the range of 1.6 - 2.2 dS m^{-1}.

Flowers petal samples at 35 days after first flowering were collected from each plot and used to determine their N, P, K, Ca, Mg, NH_4^+, and NO_3^- concentrations.

Number of flowers was recorded over the year and considered as plant yield. Stalk length of the flowers was measured from the point of origin of stalk to the point just below the flower

Table 1. Nutrient solutions composition used in the study

$NO_3^-:NH_4^+$	NO_3^-	NH_4^+	p	K	Ca	Mg	So_4^-
(mmol L^{-1})							
100:0	12.75	0	1.25	5.5	3	1	0
80:20	10.2	2.55	1.25	5.5	3	1	1.78
60:40	7.65	5.1	1.25	5.5	3	1	4.33
40:60	5.1	7.65	1.25	5.5	3	1	6.85
Fe	Mn	Cu	Zn	Mo	B		
(µmol L^{-1})							
35	5	0.75	4	0.5	30		

head, and the average stalk length of flowers was recorded and expressed in centimeter (cm). The diameter of the flower stalk after the harvesting of the flower was measured at 15 cm of upper cut of three selected tagged stalks and the average was calculated. Diameter of disk flower was recorded at full bloom stage from the flowers harvested at peak flowering. The readings were taken from the three tagged plants and average was calculated and expressed in cm. The flowers soon after harvesting were kept in fresh water and later these flower stalks were cut to have uniform stalk length. After that, such prepared flowers were kept individually in flask containing 500 mL of tap water. Flowers were observed daily till they were found unfit for containing in vase. The vase life was expressed in terms of days from the date of harvest to the end when the cut flowers were dropping or their petals were moderately wilting (He et al., 2006). At harvesting, the randomly three selected tagged flower stalks, plant roots, and shoots were dried at 80°C for 48 h and weighted.

All plant tissue samples used for chemical analysis were initially washed by distilled water, dried at 65°C to constant weight and grinded. The determination of total N in the grinded material was done based on the Kjeldahl method (Shiri et al., 2016) The P content of samples was determined by the vanadate-molybdate colorimetric method, K was determined by flame photometric method, and Ca and Mg were measured using atomic absorption spectroscopy (Shiri et al., 2016). Ammonium was determined by electrophilic substitution of salicylate acid and NH_4^+ was determined using a modified Berthelot reaction (Dias et al., 2015).

Analysis of variance (ANOVA) was performed using the SAS statistical software (SAS 9.1; SAS Institute, Cary, NC, USA). The Least Significant Difference (LSD) test was employed to compare the means of treatments under different nitrogen forms ratio at a confidence level of 95%. Correlations between the traits were determined using the Pearson correlation coefficients by SPSS software.

Results

Macronutrient Concentration in Leaves

Results showed a significant ($P \leq 0.01$ or $P \leq 0.05$) difference between cultivars and the nutrients content of the leaves tissue (Table 2). Content of N, P, Mg, NO_3^-, and NH_4^+ were higher in 'Stanza', while maximum K and Ca concentration was recorded in 'Double Dutch'. Different $NO_3^-:NH_4^+$ ratios had highly significant effects on the nutrient concentration of the leaves tissue (Table 2).

As shown in Table 3, nitrogen concentration increased as NH_4^+ concentration increased in the solution. The maximum concentration of P was observed in plants irrigated with solutions having a $NO_3^-:NH_4^+$ ratio 80:20 and 40:60 and the lowest concentration of that was observed when nutrient solution did not have ammonium. Content of K was higher when the plants were nourished with solutions with a ratio $NO_3^-:NH_4^+$ equal to 60:40, however, when the ratio was equal to 40:60, the concentration of this nutrient was minimal (Table 3). The decrease in Ca concentration in leaves was obtained when plants were fed with a ratio equal to 40:60, while with an 80:20 ratio, the greatest Ca concentration in leaves of gerbera (Table 3) was recorded. Concentration of Mg was higher when plants were irrigated with a ratio 80:20, when the ratio was lower, Mg concentration decreased (Table 2). The data showed that by increasing NO_3^- proportion in nutrient solution, concentration of this ion increased in leaves of gerbera, while NH_4^+ content decreased. Maximum NO_3^- content was found with the 100:0 $NO_3^-:NH_4^+$ ratio while maximum NH_4^+ was observed with 40:60 ratio (Table 2).

Flower characteristics

Flower number per year (FNY), flower stalk length (FSL) and flower disk diameter (FDD) were significantly higher in 'Stanza', while the amount of inflorescence fresh and dry weight (IFW and IDW) and vase life (VL) were higher in 'Double Dutch' (Tables 4 and 5). The results showed a significant difference ($P \leq 0.01$ or $P \leq 0.05$) among $NO_3^-:NH_4^+$ ratios in the flower characteristics (Table 5). Flower number per year was decreased when NO_3^- was the sole source of N (Table 5).

Table 2. Analysis of variance of the effects of NO_3^-:NH_4^+ ratios and cultivars on leaves nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), ammonium (NH_4^+), and nitrate (NO_3^-) content of gerbera cut flowers

Analysis of variance	N	P	K	Ca	Mg	NH_4^+	NO_3
Cultivar	ns	**	ns	**	*	*	**
NO_3^-:NH_4^+ ratios	**	**	**	**	**	**	**
Cultivar*N. ratio	ns	ns	ns	ns	ns	ns	ns
CV%	8.37	17.73	8.24	15	12.29	8.96	3.42

ns - non-significant, * significant at 0.05, ** significant at 0.01

Table 3. Effects of NO_3^-:NH_4^+ratios and cultivars on leaves nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), ammonium (NH_4^+), and nitrate (NO_3^-) content of gerbera cut flowers

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	NH_4^+ (mg/g)	NO_3^- (mg/g)
Cultivar							
Stanza	2.95 a	0.37 a	2.9 b	1.17 b	0.42 a	0.39 a	2.38 a
Double Dutch	2.78a	0.28 b	3.16 a	1.79 a	0.33 b	0.35 b	2.3 b
LSD	0.21	0.05	0.21	0.19	0.04	0.03	0.07
NO_3^-:NH_4^+ ratios							
100:0	2.51c	0.16 c	3.07 ab	1.65 ab	0.37 ab	0.29 c	2.86 a
80:20	2.7bc	0.42 a	2.96 b	1.74 a	0.41 a	0.19 d	2.56 b
60:40	2.94b	0.27 b	3.29 a	1.39 bc	0.37 b	0.41 b	2.07 c
40:60	3.33a	0.42 bc	2.52 c	1.14 c	0.34 b	0.58 a	1.87 d
LSD	0.29	0.07	0.3	0.27	0.06	0.04	0.1

Values in a columns followed by different letters are significantly different at 5%

Table 4. Analysis of variance of the effect of NO_3^-:NH_4^+ ratios and cultivars on flower number per year (FNY), flower stalk length (FSL), flower stem diameter (FSD), flower disk diameter (FDD), inflorescence fresh weight (IFW), inflorescence dry weight (IDW), and vase life (VL) of gerbera cut flowers

Analysis of variance	FNY	FSL	FSD	FDD	IFW	IDW	VL
Cultivar	**	**	*	**	**	**	**
NO_3^-:NH_4^+ ratios	**	**	**	**	*	**	**
Cultivar*N. ratio	ns	ns	ns	ns	ns	ns	ns
CV%	8.14	3.32	8.37	6.24	10.37	14.10	5.45

ns - non-significant, * significant at 0.05, ** significant at 0.01

Table 5. Effects of NO_3^-:NH_4^+ ratios and cultivars on flower number per year (FNY), flower stalk length (FSL), flower stem diameter (FSD), flower disk diameter (FDD), inflorescence fresh weight (IFW), inflorescence dry weight (IDW), and vase life (VL) of gerbera cut flowers

Treatment	FNY	FSL (cm)	FSD (cm)	FDD (cm)	IFW (g)	IDW (g)	VL (day)
Cultivar							
Stanza	301.58 a	40.65 a	0.78 b	11.84 a	29.81 b	3.83 b	12.31 b
Double Dutch	267 b	37.44 b	0.85 a	10.91 b	34.58 a	4.68 a	13.27 a
LSD	20.02	1.12	0.06	0.61	2.89	0.52	0.61
NO_3^-:NH_4^+ ratios							
100:0	245.17 b	40.67 a	0.78 b	11.07 b	33.14 ab	4.04 b	13.92 a
80:20	314.00 a	39.63 ab	0.92 a	12.29 a	36.13 a	5.23 a	14.20 a
60:40	322.00 a	39.08 b	0.87 a	12.07 a	30.56 bc	4.15 b	12.87 b
40:60	256.00 b	36.82 c	0.68 c	10.08 c	28.95 c	3.63 b	10.18 c
LSD	28.31	1.59	0.08	0.86	4.09	0.74	0.85

Values in a columns followed by different letters are significantly different at 5%

Flower number per year changed between 245 and 322 stalk year^{-1}. The highest and lowest numbers of flowers were obtained by the 60:40 ratio of NO_3^-:NH_4^+ and sole NO_3^- treatment, respectively (Table 5). Flower stalk length was higher with the increase of the proportion of NO_3^-, showing its peak in the ratio 100:0 of NO_3^-:NH_4^+ in nutrient solution (Table 5). The diameter of the flower disk was higher in plants irrigated with NO_3^-:NH_4^+ with ratios 80:20 and 60:40 in nutrient solution (Table 5). The highest IDW was obtained from the gerbera plants fed with 80:20 ratio of NO_3^-:NH_4^+, while the lowest IFW and IDW were obtained with 40:60 ratio of NO_3^-:NH_4^+. Data showed that by increasing of NH_4^+ proportion higher than 20% of total N, IFW as well as IDW were decreased (Table 5). The VL increased when NO_3^- proportion increased in nutrient solution. The longest VL (14.20 days) had to the gerbera plants irrigated with 80:20 NO_3^-:NH_4^+ ratio while the shortest VL (10.18 days) was found with 40:60 $NO3^-$: NH_4^+ ratio (Table 5).

Pearson correlation analysis was carried out to determine the relationship between the traits (Table 6). Negatively correlated with N were NO_3^-, FSL, and VL. Correlations between Ca with Mg, FSL and IFW were significantly positive. Also, there were significant positive correlations between Mg and FSD, FDD, IFW, IDW, and VL.

Discussion

Macronutrient concentration

It is demonstrated that NO_3^-or mixtures of NO_3^- with low proportions of NH_4^+ are the best compositions for N nutrition in plants due to the adverse effect of a N nutrition based on high proportions of NH_4^+ (Chen et al., 2005; Mendoza-Villarreal et al., 2015).

Plants response to continuous irrigation with NH_4^+ depends on the species, which translates to a decrease in growth and quality of plants (Mendoza-Villarreal et al., 2015). Most variables studied in this research showed that increasing the ratio of NH_4^+ more than 40% negatively affects the growth and quality of gerbera plants. Coraspe-León et al. (2009) showed that to avoid toxicity of NH_4^+ this should not exceed 20% of the total amount of N in the nutrient solution. Increasing the concentration of NH_4^+ in nutrient solution showed a decrease of macronutrients content, except P and NO_3^-, in plant leaves.

Cultivars evaluated in this study showed marketable differences in the content of macronutrients in the leaves. Our results are supported by Zhang et al. (2012) and James and van Iersel (2001) in petunia cultivars. Except for K and Ca, 'Stanza' has higher content of macronutrient in its leaves.

The higher N content in leaf tissues was observed with increased NH_4^+ concentration in the nutrient solution. This is in agreement with the findings of Kraus et al. (2002) in *Cotoneaster* and *Rudbeckia*, Lorenzo et al. (2000) in rose and Tabatabaei et al. (2008) in strawberry, who reported that the addition of NH_4^+ proportion in a nutrient solution produced a greater total N uptake.

The lowest tissue phosphorus content was obtained when the rate was 100:0 (NO_3^-:NH_4+); this result being significantly lower than the ones for all the other treatments. The high proportion of NH_4^+ in the nutrient solution resulted in the highest phosphorus concentration.

Results observed for P in this study are in agreement with results of Latigui et al. (2011) for strawberry and Mendoza-Villarreal et al. (2015) for lisianthus.

Plants irrigated with high proportion of NH_4^+ indicated a K decrease attributed to competition for uptake sites (Hoopen et al.,

Table 6. Pearson correlation coefficients among evaluated characteristics in gerbera cut flowers of 'Stanza'

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. N	1													
2. P	0.618^{ns}	1												
3. K	- 0.637^{ns}	- 0.635^{ns}	1											
4. Ca	- 0.932^{ns}	- 0.298^{ns}	0.526^{ns}	1										
5. Mg	- 0.676^{ns}	0.093^{ns}	0.473^{ns}	0.882*	1									
6. NH_4	0.892^{ns}	0.216^{ns}	- 0.539^{ns}	- 0.992**	- 0.931*	1								
7. NO_3	-0.959*	- 0.551^{ns}	0.398^{ns}	0.897*	0.588^{ns}	- 0.938^{ns}	1							
8. FN	- 0.032^{ns}	0.302^{ns}	0.539^{ns}	0.228^{ns}	0.601^{ns}	- 0.336^{ns}	- 0.200^{ns}	1						
9. FSL	- 0.988**	- 0.689^{ns}	0.740^{ns}	0.894*	0.642^{ns}	- 0.856^{ns}	0.911*	0.092^{ns}	1					
10. FSD	- 0.566^{ns}	- 0.004^{ns}	0.718^{ns}	0.725^{ns}	0.909*	- 0.794^{ns}	0.373^{ns}	0.832^{ns}	0.595^{ns}	1				
11.FDD	- 0.550^{ns}	- 0.062^{ns}	0.776^{ns}	0.683^{ns}	0.862*	- 0.752^{ns}	0.337^{ns}	0.851^{ns}	0.594^{ns}	0.994**	1			
12. IFW	- 0.785^{ns}	0.001^{ns}	0.325^{ns}	0.953*	0.941*	- 0.968*	0.780^{ns}	0.296^{ns}	0.718^{ns}	0.731^{ns}	0.667^{ns}	1		
13.IDW	- 0.529^{ns}	0.288^{ns}	0.326^{ns}	0.790^{ns}	0.980**	- 0.854^{ns}	0.458^{ns}	0.634^{ns}	0.482^{ns}	0.871^{ns}	0.814^{ns}	0.907*	1	
14. VL	- 0.947*	0.437^{ns}	0.729^{ns}	0.965^{ns}	0.852*	- 0.963*	0.846^{ns}	0.343^{ns}	0.947*	0.800^{ns}	0.748^{ns}	0.865*	0.733^{ns}	1

ns - non-significant, * significant at 0.05, ** significant at 0.01

2010; Mendoza-Villarreal et al., 2015) due to the similarities in both cations (Xu et al., 2002). In the present study, gerbera showed a decrease in K concentration as NH_4^+ in the nutrient solution was increased, especially when its proportion was from 20% to 60% of total N.

An excessive NH_4^+ proportion has been recorded to cause a decrease in Ca concentration in plant tissues due to the antagonism between both cations (Mendoza-Villarreal et al., 2015; Siddiqi et al., 2002). In the present experiment, gerbera showed a decrease in Ca concentration as NH_4^+ in the nutrient solution was increased, especially when its proportion was from 20% to 60% of total N. In rose (Bar-Yosef et al., 2009) and *Iris* (Zhao et al., 2016) low pH with higher percentage of NH_4^+ in solution caused Ca and K reduction in plant leaves and that was the same as our results.

The highest rate of Mg_2^+, 0.48%, was obtained in gerbera root irrigated with 100:0 and 80:20 (NO_3^-:NH_4^+). Kotsiras et al. (2002) reported that the presence of a high proportion of NH_4^+ in a nutrient solution induced a decrease of this element in the tissue contents, while NO_3^- had the inverse effect.

The higher content of NH_4^+ was observed with increased NH_4^+ proportion in the nutrient solution as highest value was recorded in plant fed with 60% NH_4^+ proportion. This is supported by the finding of Tabatabaei et al. (2008) in strawberry, Bybordi et al. (2009) in canola, and Lorenzo et al. (2000) in rose, who reported that the addition of ammonium in a nutrient solution causes NH_4^+ uptake increase. High content of NH_4^+ in the nutri¬ent solution may cause NH_4^+ toxicity, which is considered to be the result of effects such as NH_4^+ induced nutrient deficiency caused by wrecked uptake of ions, acidification of the root zone (Fig. 2), alteration in the osmotic balance, modi¬fication of phytohormone, and impaired N enzyme metabolism (Bybordi et al., 2009; Lorenzo et al., 2000).

The highest NO_3^-concentration was recorded in plant leaf tissue irrigated with 60% NH_4^+ proportion. When higher NO_3^-proportion was supplied to the plants, the concentration of NO_3^-in leaf tissue increased. This result agrees with the findings of Mengel and Viro (1978) and Bybordi et al. (2009). Leachate EC was higher in media fed with higher NH_4^+ ratio (Fig. 1). Higher NH_4^+ ratio probably led to lower pH that increased solubilization of salt elements from fertilizer. Higher EC as well as low pH adversely affect plant growth and nutrient uptake as it was reported for *Iris* (Zhao et al., 2016) and rose (Bar-Yosef et al., 2009).

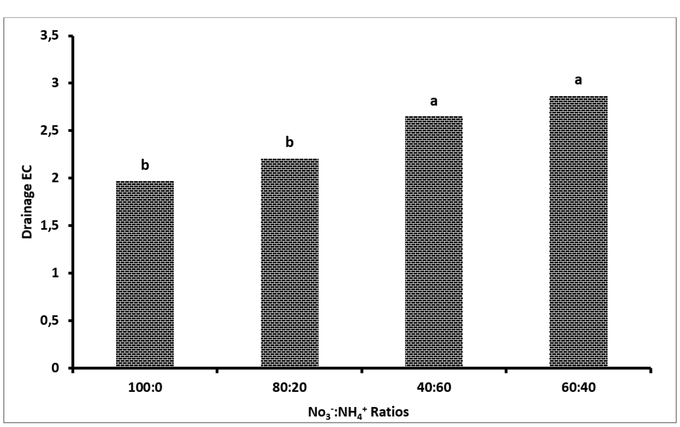

Figure 1. Effects of NO_3^-:NH_4^+ ratios on Substrate Drainage EC (dS m^{-1})

Flowering characteristics

Cut flower yield and its quality are highly momentous for selection of the particular cultivar that is suitable for commercial production. Flower quality and yield characteristics such as stalk length, and head and stalk diameter can be changed by growing seasons, cultivars, and production techniques such as soil or soilless culture systems (Şirin, 2011).

Our experiment showed clear evidence of importance of cultivar variation in the susceptibility of flowers yield and quality to the N form supplied. The effectiveness of nitrogen forms in our study was reflected in the flower number, flower disk diameter, inflorescence fresh weight, and stalk length that was observed in 'Stanza' cultivar, while it was reflected in stalk diameter, inflorescence dry weight, and vase life in 'Double Dutch' cultivar.

Maximum flowers number recorded in 'Stanza' (302 stalk year^{-1}) that was 13% higher than in 'Double Dutch' (267 stalk year^{-1}) might be attributed to the more nutrient uptake and plant leaves number as well as plant development resulted in production and accumulation of maximum biomass, resulting with the production of higher number of flowers with bigger size. The results are in accordance with the findings of Savvas et al. (2003) in gerbera under protected conditions. Higher stalk length was observed in 'Stanza' (40.65 cm) while smaller was 37.44 cm in 'Double Dutch' (Table 3). Higher content of P affects higher FSL. The stalk length is important genetically important feature; therefore it is expected to vary between the cultivars as it was earlier observed by Polara et al. (2014).

Cultivar 'Stanza' FDD was significantly greater than in 'Double Dutch' (Table 3). The bigger flower diameter of 'Stanza' might be due to the intrinsic characters of cultivars as observed by finding of Shammy et al. (2012).

'Double Dutch' has significantly higher IFW than 'Stanza' (Table 3). The results are in accordance with Savvas et al. (2003) that found difference variation in gerbera cultivars.

Vase life of 'Double Dutch' is significantly higher than in 'Stanza' cultivar (Table 3). Variation in VL among cultivars may be attributed to variations in their genetically make up. Higher IDW and Ca concentration in leave can cause higher VL of 'Double Dutch' (Tables 2 and 3). Calcium plays an important role in plant cell functions, such as cell elongation and division, N and carbohydrate metabolism, and plant cell membrane integrity (Deng et al., 2020; Shiri et al., 2016).

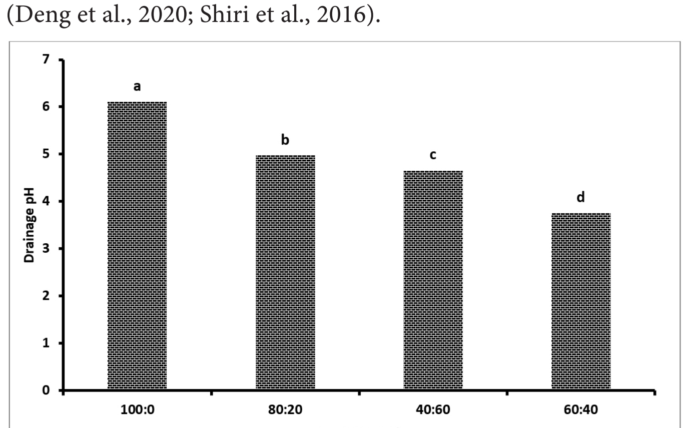

Figure 1. Effects of NO_3^-:NH_4^+ ratios on Substrate Drainage pH

This study showed better growth conditions using mix nitrogen forms as the N source, compared to NO_3^- as the sole N source or high proportion of NH_4^+ (Table 3). Under high nitrate (100%) and ammonium (60%) concentrations, the growth and biomass production of plants were strongly reduced compared with other treatments.

Carr et al. (2020) observed that NO_3^- nutrition was more effective than NH_4^+ nutrition for sustaining plant growth. Authors stated that because of substrate acidification by high proportion of NH_4^+ use, it is possible that low pH can be reason of the observed growth inhibition. In this experiment, pH varied between treatments and decreased by increase of NH_4^+ proportion or sole NO_3^- (Fig. 2). The maximum number of flowers observed in 60% NO_3^-:40%NH_4^+ and 80%NO_3^-:20%NH_4^+ (31% and 28%, respectively, higher than sole NO_3^-), indicating that nutrient solution with 20 - 40% ammonium promoted the flower number of gerbera. Song et al. (2012) had the same results in Chinese kale, but Mendoza-Villarreal et al. (2015) found higher flower number of *Lisianthus* with high proportion NH_4^+ in nutrient solution.

The shortest stalk length was recorded on the plants fed with the high proportion of ammonium (60%) in nutrient solution. Nelson et al. (2012) also concluded that elevated levels of NO_3^-:NH_4^+ caused slight increases in gomphrena, impatiens, petunia and marigold height.

Flower disk diameter was the highest (12.29 cm) with low supplement of ammonium (20%) followed by (40%) (12.07 cm) significantly differ from high NH_4^+ proportion in nutrient solution and NO_3^- as a sole N source, indicating that nutrient solution with 20 - 40% ammonium promoted the growth of gerbera FDD. The same results in flowering cabbage got Song et al. (2012).

The findings of the present study showed that the IDW of gerbera grown with the 20% ammonium were higher (5.23 g) than those grown with other nutrient solutions. Walch-Liu et al. (2000) reported that excessive NH4+ was harmful to plants and could result in hormonal imbalance, which could then hamper growth and reduce yield. The vase life was evaluated to the end when the cut flowers were dropping or their petals were moderately wilting (Macnish et al., 2008).

As shown in Table 3, plants irrigated by nutrient solution with 20% NH_4^+ had 39% higher VL than in plants fed by nutrient solution with 60% NH_4^+. Pettersen and Gislerod (2003) also observed that the reduced VL of gerbera inflorescence could be caused by low carbohydrate content. High concentration of NH_4^+ might be due to the unavailability of NO_3^- as a N source and the higher demand of carbohydrates needed for NH_4^+ assimilation and detoxification (Tabatabaei et al., 2008).

Conclusions

Sustainable cut flower production needs optimal fertilization to achieve a high ornamental value and to reduce production costs. Hydroponic cultivated gerbera cut flowers need high nutrient inputs in order to meet growth demands and these require to be supplied by fertilizers in nutrient solution. The different cultivars of gerbera showed similar results of flower quality and quantity as well as nutrient uptake response to NO_3^-:NH_4^+ ratios.

According to the present study, gerbera for cut flower cannot tolerate higher then 40% of N in the form of NH_4^+ because higher levels are toxic. The maximum plant growth was observed in NO_3^-:NH_4^+ ratio at 80:20. Thus a higher production and quality can be achieved by this ratio.

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