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Full Length Research Paper

Effects of different nutrient solution formulations on yield and cut flower quality of gerbera (*Gerbera jamesonii*) grown in soilless culture system

Uğur Şirin

Department of Horticulture, Faculty of Agriculture, Adnan Menderes University, 09100 Aydin, Turkey.
E-mail: usirin@adu.edu.tr. Tel: +90 256 7727024. Fax: +90 256 7727233.

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This research was conducted to determine the effects of different nutrient solution formulations on the yield and quality of cut flowers and growth of gerbera plants in substrate culture system. Five different nutrient solution formulations were used. The gerbera plantlets were planted into pots filled with perlite and peat mixture, and values of flower yield and cut flower quality criteria, and several parameters related to growth performance such as number of daughter plants, root growth criteria, plant fresh weight were obtained. The best results of cut flower yield, flower quality and plant growth were obtained from gerberas nourished by the "Çolakoğlu-2" nutrient solution formulation which consists of 150 ppm N, 31 ppm P, 234 ppm K, 30 ppm Mg, 100 ppm Ca, 15 ppm S, 8 ppm Fe, 5 ppm Mn, 1.5 ppm B, 2 ppm Cu, 3 ppm Zn and 0.2 ppm Mo. The highest flower yield was 38.67 flowers per plant in this solution. The highest value of the number of daughter plants (3.53/plant) in gerbera was determined in the "Çolakoğlu-2" nutrient solution formulation.

Key words: *Gerbera jamesonii*, nutrient solution formulation, quality, yield, cut flower, substrate culture.

INTRODUCTION

Turkey has 1200 ha production area of cut flower species in 2005 (Anonymous, 2008). Gerbera production area consists of 8.6% of total cut flower production area of Turkey (Kazaz, 2006). *Gerbera jamesonii* is one of the most important cut flower species successfully grown in greenhouse conditions in Turkey and in the world, and it is a member of the Compositae family. This species has a great potential and future for production and exportation on the condition that it is sufficiently promoted and the appropriate agricultural technologies are applied. Gerbera flowers have a wide range of petal colours as red, white, orange, yellow etc., and the most popular cultivars are the red ones in markets by consumers. Flowering time, flower yield per plant (5.5 to 80 flowers/per plant), quality parameters such as stalk length, head diameter,etc can be changed by growing seasons, cultivars and production techniques such as in soil or soilless culture systems (Moltay et al., 1998; Maloupa and Gerasopoulos, 1999; Özzambak and Zeybekoğlu, 2004).

In Turkey, production of gerbera are realised conventionally in soil. In soil production, the fertilizer requirements of gerbera plants can be provided by using 45 g of one of the 15-15-15 composite fertilizer kinds per square meters before planting (Altan and Altan, 1984). Also, optimum levels of nutrient elements required by gerbera plants in soil production were mentioned by Özzambak and Zeybekoğlu (2004) as follows; N 4.0, P 0.2, K 1.5, Mg 1.2, Ca 2.0, S 1.5, Na<2.0, Cl<2.0 mmol/L, Fe 12.0, Mn 1.5, Zn 2.0, B 12.0 and Cu 1.0 µmol/L. However, in recent years, especially in greenhouse production, there is an increasing interest in the use of soilless culture due to several reasons in particular related to soil borne pest and disease problems (Tüzel et al., 2001) such as *Phytoptora cryptogea, Rhizoctonia, Fusarium, Botrytis* (Özzambak and Zeybekoğlu, 2004), soil infertility and fatigue, and accumulation of toxic elements in soil. For this reason, soilless culture systems can be used in order to prevent negative effects of soil on plants and provide an appropriate culture environment in production of cut flower species.

Soilless culture technique which is the most intensive system of production in horticulture and floricultural crops, has been used for several years in the Mediterranean countries and Europe (Maloupa et al., 1992; Brun et al., 2001). The commercial utilization of soilless culture is increasing rapidly in Turkey in recent years. At the same time, many scientific researches were conducted, especially on vegetable and ornamental production, on soilless culture (Altan and Baktir, 1980; Gül, 1991; Cervelli et al., 1994; Özgümüş et al., 1997; Sevgican, 1999; Raviv and Blom, 2001; Savvas et al., 2003). Maintaining optimal conditions for growth and development requires proper climate management and the use of well-balanced irrigation solutions that meet the mineral requirements of specific crops and cultivars (Zekki et al., 1996). Plants take up nutrients and water in ratios which fluctuate widely during the growing period (Savvas and Manos, 1999).

Therefore, nutrification has a great importance for plant growth and yield in soilless culture. In soilless culture, all the essential elements are supplied to the plants by dissolving fertilizer salts in water to make up the nutrient solution. Different varieties and plant species have different nutrient requirements (Resh, 1991; Sevgican, 1999). When inappropriate nutrient elements and dosage which comprised the nutrient solutions, are used for plant nutrition, some nutritional disorders may occur. A nutritional disorder is a malfunction in the physiology of a plant resulting in abnormal growth caused by either a deficiency or excess of mineral elements (Resh, 1991). An increase in nutrient solution concentration to produce high-qualified crops may reduce growth and yield (Shwarz et al., 2002). For example, when the ammonium, which is a form of N, concentration in the external solution is very high, the root growth may be additionally suppressed (Savvas et al., 2003). At the same time, disorders of one element often upset the plants ability to accumulate other elements. A deficiency of one element leads to antagonism toward the uptake of other element (Resh, 1991). Moreover, there is a relation between the pH of substrate and nutrient solution contents. Form and interrelation of various fertilizer salts used in a nutrient solution formulation affect the plants growth. The basic step to solve the problem of deficiency or excess of nutrient elements for growth of species is to establish an appropriate nutrient solution formulation.

Such works on plant nutrition conducted by De Saussure, Boussingault, Sachs, and Knop, dates back as early as the 1800s. "In following years, researchers developed many diverse basic formulas for the study of plant nutrition. Some of these workers were Tollen (1882), Tottingham (1914), Shive (1915), Hoagland (1919), Trelease (1933), Arnon (1938) and Robbins (1946)" (Resh, 1991). While some of the nutrient solution formulations used in soilless culture such as Hogland and Knop, have wide usage potentail, some of them are specified only for vegetable production and for some other soilless culture systems. Although it is aimed to contain more nutrient elements in general-used nutrient solutions and plant uptake relies on the need for these elements, it is much more healthier to use appropriate nutrient solutions for each species.

An optimum formulation depends on plant species and variety, stage of plant growth, part of the plant representing the harvested crop, season of the year-day length and weather conditions such as temperature, light intensity, sunshine hours. At the same time, it must be considered that the susceptibility of different plant species to various nutritional disorders varies greatly (Resh, 1991). Therefore, it is required to establish the favorable nutrient solution formulations for each plant species. As different plant species and varieties have different nutrient element and dosages requirements, all the nutrient elements have different effects on plant growth, too. In addition to this, it is necessary to apply good and suitable nutrient solutions to gerbera plants for high yielded and good qualified flower production in soilless culture. In ornamental production, the aim is to obtain high and qualified yield and this could be achieved by using an appropriate fertilization in terms of amount and composition.

In relation to the aim of this study, not any research was found on nutrient solution formulations specified on gerbera production in soilless culture. Therefore, in this study, it is aimed to determine the suitable nutrient solution formulation for gerbera production for high yielded and well qualified cut flower production in substrate culture by using some formulations which was used before for other species and for general purposes.

MATERIALS AND METHODS

The research took place in an unheated greenhouse in 2005 to 2007 seasons and *G. jamesonii* cv. "Skyline" was used as plant material. As production system, "Pot culture", one of the soilless culture systems was used and gerbera plantlets were planted on 08 June 2005 in plastic horizontal pots which have 26 L volume and consist of two plantlets in each pot. 15 plastic pots were used per application with 30 plants. In each application, plants were placed into pots with 35 x 40 cm planting intervals, the distance between rows is 35 cm and the distance between the plants within the row should be 40 cm. Perlite and peat mixture (1:1) was used as substrate in the study. Five different nutrient solution formulations (NSF) were used to nourish the gerbera plants; three of them were used as materials according to the cited works (Hoagland and Arnon, 1950; Hewitt, 1966; Steiner, 1984) and two of them, which were suggested by Çolakoğlu to use for seedling growing of figs, were used according to the work of the Kilinç (2005). The extensive literature review offered no finding about a special NSF for gerbera production. For this reason, other available NSFs which were used before for vegetable and fruit productions for general multipurpose were used in the applications of this research.

Table 1 presents the NSFs used in this study with their contents. The formulations which were used, include all the nutrient elements

Table 1. Nutrient solution formulations (NSFs) which were used in the study.

Nutrient elements	Number of nutrient solution formulation				
	1-NSF	2-NSF	3-NSF	4-NSF	5-NSF
	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})
N-Nitrogen	210	168	50	167	150
P-Phosphorus	31	41	26	31	31
K-Potassium	234	156	66	277	234
Mg-Magnesium	48	36	10	49	30
Ca-Calcium	160	160	33	183	100
S-Sulphur	64	48	5	111	15
Fe-Ferrous	2.5	2.8	2.6	1.33	8
Mn-Manganese	0.5	0.55	1.6	0.62	5
B-Boron	0.5	0.54	0.50	0.44	1.5
Cu-Copper	0.02	0.064	0.66	0.02	2
Zn-Zinc	0.05	0.065	1.0	0.11	3
Mo-Molybdenum	0.01	0.048	0.066	0.048	0.2
	Hoagland and Arnon, 1950	Hewitt, 1966	Çolakoğlu-1 (Kılınç, 2005)	Steiner, 1984	Çolakoğlu-2 (Kılınç, 2005)

Table 2. Chemical sources of nutrient elements were given which were used to prepare nutrient solutions.

Nutrient elements	Chemical sources
N	NH_4NO_3 (33%)
P	P_2O_5 (85%)
K	K_2SO_4 (50%)
Mg	$MgSO_4 .7H_2O$ (10%)
Ca	$Ca(NO_3)_2$ (15.5% N, 26% CaO)
S	S is not applied because of using some fertilizers consist of SO_4
Fe	FeEDDHA (6%)
Mn	$MnSO_4.H_2O$ (28% Mn)
B	H_3BO_3 (17% B)
Cu	$CuSO_4.5H_2O$ (22% Cu)
Zn	$ZnSO_4.7H_2O$ (25% Zn)
Mo	$(NH_4)_6$ $Mo7O_2.4H_2O$

necessary for plant vegetation period and in Table 2 chemical sources of nutrient elements which were used to prepare nutrient solutions were given.

An open soilless culture system, which was irrigated and nourished by drip irrigation system, was used in this trial. For each nutrient solution, a nutrient tank of 220 L capacity was used; in sum, five nutrient tanks each of which consists of a pump that was used to pump out the solutions from the tanks to the laterals were used. In all NSFs except for the Çolakoğlu-2 (5th) NSF, plants were nourished daily with nutrient solutions including all the essential macro and micro nutrient elements in all applications.

In the 5th NSF, all the nutrient elements that will be required by the gerbera plants in all vegetation period, were mixed with substrate at the beginning of the cultivation period; hence, afterwards the plants were only irrigated till the end of the vegetation (Kilinc et al., 2007). The plants were irrigated 3 or 4 times per day in all applications depending on the calculated drainage percentage in the previous watering applications (Maloupa and Gerasopoulos, 1999; Özzambak and Zeybekoğlu, 2004). In all applications, the entire quantity of drainage nutrient solution and irrigation water were collected after irrigation, and not recycled to nourish the gerberas. This system is called an “open soilless culture” which is one of the hydroponic systems. Because of impracticability for long term productions in soilless systems based on continual nutrient solution recirculation, open soilless system was used.

Every week and after all replenishment of irrigation water with nutrient solution, the pH of irrigation water was measured and set at 6.0 in all applications (Özzambak and Zeybekoğlu, 2004; Dole and Wilkins, 2005). The measurements were taken from the tanks and substrate. The EC of nutrient solutions applied to the plants was identical in all applications with its level between 1.5 to 2 dSm^{-1}

Table 3. The description of abbreviations used in text.

Abbreviation of trait	Trait description
NSFs	Nutrient solution formulation(s)
CFY	Cut flower yield per plant
FSL	Flower stalk length (cm)
FHD	Flower head diameter (cm)
FSBD	Flower stalk below diameter (mm)
FSUD	Flower stalk upper diameter (mm)
FSFW	Flower stalk fresh weight (g)
FSDW	Flower stalk dry weight (g)
VL	Viselife (day)
NDP	Number of daughter plants
RFW	Root fresh weight (g)
RDW	Root dry weight (g)
RL	Root length (cm)
NR	Number of roots per plant
PFW	Plant fresh weight (g)

Table 4. The effect of nutrient solution formulations on cut flower yield per plant.

Number of nutrient solution formulation (NSFs)	Cut flower yield (CFY) per plant (Number/plant)
1	21.67^{bc}
2	23.67^{b}
3	13.67^{c}
4	19.67^{bc}
5	38.67^{a}
LSD 5%	9.381**

(Sonneveld and Voogt, 1983; Mercurio, 2002; Özkan et al., 2006). To observe the effects of five different NSFs on yield of cut flower gerberas; number of flowers harvested per plant per replication was recorded weekly. The first flower harvest took place on 02 September 2005. During the whole vegetation period, all flowers were harvested by the criteria of commercial ripening. After harvests, flower stalk length (cm), flower head diameter (cm), flower stalk below diameter (mm), flower stalk upper diameter (mm), flower stalk fresh weight (g), flower stalk dry weight (g) and viselife (day) (Table 3) were measured at each harvesting, to determine the quality of the cut flowers harvested from gerbera plants in all vegetation periods which consist of 16 months.

At the end of the vegetation period, gerbera plants were uprooted on 16 October 2006. Number of daughter plants per plant, fresh weight of gerbera plants (g), root fresh weight (g), root dry weight (g), root length (cm), number of roots of all uprooted plants per application and per repetition were measured to determine the growth performance of gerberas (Table 3). The trial was conducted in the completely randomized block design with three replicates. Data were subjected to analysis of variance (ANOVA). The means were compared using the least significant difference (LSD) test by JMP (SAS, 1996). All analyses of significance were made at the $P<0.05$ level of significance.

RESULTS

Findings on cut flower yield

In this study which analyzed the effects of different NSFs on yield and cut flower quality of gerbera (*G. jamesonii*) grown in substrate culture system, all marketable flowers, among the ones harvested between September 2, 2005 and October 16, 2006, were counted and the flower yield per plant was calculated by dividing the total number of flowers into the total number of plants in the application. The first flowers of gerbera plants were picked up and taken away from the plant right after the cultivation in the first stage of the development period. The flowers that burst 2 months after the cultivation were harvested and integrated to the cultivation values. Table 4 presents the cut flower yield per plant which was nourished with the NSFs in the trial.

ANOVA revealed statistically significant differences between the five different NSFs in terms of CFY per plant

Table 5. The effects of nutrient solution formulations on growth performances of gerbera plants.

Application (no. of NSFs)	Traits					
	NDP (no)	PFW (g)	RFW (g)	RDW (g)	RL (cm)	NR (no)
I	1.40^{b}	104.120^{b}	101.556^{b}	23.271^{b}	38.85^{b}	60.967^{b}
II	0.70^{b}	74.911^{b}	80.301^{b}	18.576^{b}	39.90^{b}	52.767^{b}
III	1.40^{b}	63.278^{b}	95.199^{b}	22.523^{b}	41.11^{b}	61.933^{b}
IV	1.17^{b}	69.795^{b}	78.129^{b}	19.614^{b}	38.75^{b}	52.600^{b}
V	3.53^{a}	209.469^{a}	267.392^{a}	72.257^{a}	53.03^{a}	128.633^{a}
LSD (5%)	1.069**	42.123**	47.544**	13.906**	7.720*	21.548**

Table 6. F- values from the variance analysis of cut flower yield, growth performance and flower quality traits as affected by five different nutrient solution formulations (NSF).

Traits	Source of variation NSFs	Traits	Source of variation NSFs
CFY	10.427**	FSL	2.191^{ns}
NDP	11.192**	FHD	5.257*
PFW	22.193**	FSBD	6.383*
RFW	30.500**	FSUD	9.283**
RDW	29.140**	FSFW	5.312*
RL	6.559*	FSDW	3.279^{ns}
NR	23.928**	VL	2.118^{ns}

of gerberas. The outcomes of the statistical analysis revealed that nutrition solutions which were used in this study, had significant effect on the CFY per plant of gerberas, with 99% confidence. As shown in Table 4, according to the NSFs, CFY per plant in applications changed between 13.67 and 38.67/per plant and the highest yield per plant was obtained by the 5th NSF. Assuredly, it was thought that this situation was associated with the healthy vegetative growth of gerbera plants, as total nutrient elements were applied at the beginning of the vegetation period.

In this application (5th NSF), all the macro and micro nutrient elements which will be needed by the gerbera plants during the whole vegetation period, were added to the growing medium at the beginning of the growing season.

It was found that there is a difference by 61.2% (15/plant cut flower) between the 5th and 2nd NSF, which is the closest flower of the former, in terms of the CFY. It was found that the flower yields were low in the applications, except for the 5th NSF. As for the 3rd nutrient solution, which provided the lowest CFY, 13.67 flower stalks were harvested per plant and this application included the use of N, P, K doses, which were 50 ppm N, 26 ppm P and 66 ppm K respectively.

These doses were lower than those of the other solutions.

Findings on cut flower quality of gerberas

Measurements and observations were made on the flowers for a period of 13.5 months, starting on September 2, 2005 when the flowers were first harvested within the 16 month growth period following the date of cultivation to determine their qualities. For this purpose; on the harvested cut flowers, FSL, FHD, FSBD, FSUD, FSFW, FSDW and VL were determined. Variance analyses were made on the values obtained to find out whether there is difference between the qualities of the cut flowers in terms of the NSFs applied on them or not. *F* –values from variance analysis were given in Table 5. According to the NSFs used in this research, the flower stalks harvested from gerbera plants have statistically important differences in terms of FHD, FSBD, FSFW ($P \leq 0.05$) and FSUD ($P \leq 0.01$). Besides, FSL which is one of the main criteria especially for cut flower marketing, was found to be statistically insignificant.

Likewise, no statistically important difference between the NSFs was obtained with respect to FSDW and VL (Table 5). As shown on Table 6, FSLs were changed between 36.373 and 39.290 cm, depending on the NSFs, and there was no significant difference in terms of stalk lengths as a result of the NSFs. The cut flowers nourished with the 2nd NSF including N, P and K, respectively; 168, 41 and 156 ppm yielded the highest

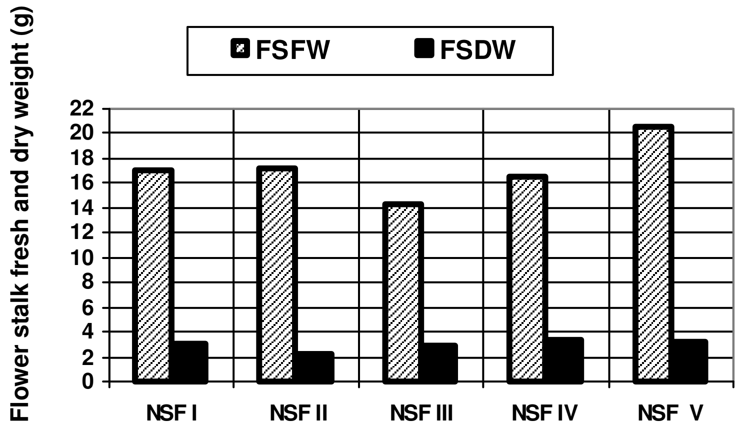

Figure 1. The changes of the fresh and dry weight of cut flower stalks according to the NSFs.

stalk lengths. The flowers with shortest stalk lengths were obtained from the plants nourished with the 4th NSF including 167 ppm N, 31 ppm P and 277 ppm K, respectively. The mean FSL (36.373 cm) of flowers in this NSF was approximately 3 cm shorter than those of the NSFs that yielded the highest stalk lengths. Diameter of flower head (FHD) varied according to the NSFs which were applied to the gerberas ($P \leq 0.05$).

However, it was seen that there was a difference of 0.5 to 1 cm between the FHDs. This statistical difference is attributable to the fact that FHD of the 5th NSF is higher than those of the others. In the study, the highest FHD (11.450 cm) was obtained from the flowers grown with 5th NSF which comprised of 150 ppm N, 31 ppm P, 234 ppm K, 30 ppm Mg, 100 ppm Ca, 15 ppm S, 8 ppm Fe, 5 ppm Mn, 1.5 ppm B, 2 ppm Cu, 3 ppm Zn and 0.2 ppm Mo, while FHDs obtained with other NSFs were between 10.560 and 10.910 cm and there was no significant difference among them. It was observed that there was statistically significant difference between the flowers in terms of the values obtained from both points of the flower stalk diameters, which is an important quality criteria that is considered to affect the endurance period of the flowers following the harvest and decrease the risk for the stalks of the flowers to get damaged during harvest. For this reason, it was thought that nutrition of plants and contents of nutrient solutions might have a great important effect on flower's quality. The thickest FSBD was 6.030 mm in 5th NSF, which was followed by the diameters obtained by the 1st and 4th NSFs, respectively 6.018 and 6.010 mm. An analysis on the outcomes concerning the FSUD revealed that, as it was in FSBD, the thickest FSUD was obtained from the flowers grown with 5th NSF. The lowest values of FSBD and FSUD was obtained from the plants nourished with the 3rd NSF which contains the lowest ratios of N, P and K, respectively 50, 26 and 66 ppm doses.

Highest fresh weight of flowers (20.569 g), which is another important quality criteria examined in the study, was obtained from the gerbera plants nourished with the 5th NSF. No significant difference was found between the 1st, 2nd, 3rd and 4th NSFs whose FSFWs varied between 14.325 and 17.252 g. Thus these formulations made up a separate group relative to the 5th NSF.

Furthermore, it was found that FSFW in the applications including a nitrogen amount higher than 150 ppm was higher than the one obtained with the 3rd NSF. However, it was seen that the 5th NSF yielded statistically different outcomes. The FSFW obtained with the 3rd NSF in which the lowest N doses was used, remained below the expected level. Although there was no statistically significant difference among the FSDWs, they varied between 2.325 and 3.379 g according to the NSFs. The5th NSF, which yielded the highest FSFW, also yielded the second highest FSDW (3.212 g). As it can be seen on Table 6, there was statistically insignificantb difference between the 2nd and 4th NSFs although the same doses of N were used. Figure 1presents the change in the fresh and dry weight values of cut flower stalks harvested from different applications according to the NSFs used in this research. As seen on Figure 1, while FSFWs have significance by using different NSFs, FSDWs determined in, were not changed significantly according to the NSFs.

Although there was no statistically significant difference, VL of the flower stalks after the harvest varied between 9.2 and 13.0 days. When we consider the content of the NSFs, it can be seen that longest VL belonged to the 4th NSF which included the highest amount of potassium. Similarly, FSDWs of the flowers nourished with the 4th NSF was the highest one (Table 6). Presence of high dry substance on the flower stalks is an important factor which has effect on the endurance of the flower stalks . In the present study, it is estimated

Table 7. The effects of NSFs on cut flower quality parameters.

Application (no. of NSFs)	Traits						
	FSL(cm)	FHD(cm)	FSBD(mm)	FSUD(mm)	FSFW(g)	FSDW(g)	VL(day)
I	37.043	10.560[b]	6.018[a]	6.026[b]	17.059[b]	3.041	10.0
II	39.290	10.910[b]	5.856[a]	5.709[bc]	17.252[b]	2.325	9.2
III	36.477	10.867[b]	5.489[b]	5.421[c]	14.325[b]	2.860	11.7
IV	36.373	10.680[b]	6.010[a]	6.098[b]	16.546[b]	3.379	13.0
V	38.340	11.450[a]	6.030[a]	6.592[a]	20.569[a]	3.212	12.3
LSD (5%)	ns	0.486*	0.297*	0.471**	3.169*	ns	ns

that high FSDWs of the flowers grown with the 4th NSF prolonged the VL of the flowers.

Findings on growth performances of gerbera plants

The gerbera plants in all applications were uprooted on 16 October 2006 and some criteria such as number of daughter plants (NDP) grown on mother plants, root growth criteria and plant fresh weight (PFW) were determined on uprooted gerbera plants. The data on these criteria which were obtained at the end of the vegetation period were subjected to variance analysis to present the effect of different NSFs on plant growth. Table 7 shows some morphological traits related to the growth performances of gerbera plants grown by different NSFs. Variance analysis revealed that there were variables dependent on NSFs used in the trial (according to NDP, PFW, RFW, RDW, NR $p= 0.01$, if RL $p= 0.05$) (Table 5).

The best growth performance as daughter plant formation, root and plant growing was exhibited by the 5th NSF which consisted of 150 ppm N, 31 ppm P and 234 ppm K and other macro and micro elements used for gerbera plants grown in perlite-peat mixture. The highest NDP formed was found in the 5th NSF (3.53/plant), while the lowest value was found in the 2nd NSF (0.7/plant) (Table 7). The plants nourished with the 5th NSF yielded 2.5 to 5 times higher NDP than the other formulations. An analysis on the fresh weight values of the plants indicated that the highest PFW belonged to the 5th NSF which has the content of 150 ppm N, 31 ppm P and 234 ppm K. The highest fresh weight of the plant grown in the 5th NSF was 209.469 g. This was followed by the 1st NSF which has a PFW, approximately 50% less than that of the 5th NSF. As for the 3rd NSF, it provided the lowest PFW. This formulation, along with the 2nd and 4th NSFs, yielded the poorest results, in terms of other plant growth criteria applied in the study (Table 7).

A healthy root growth is of great importance for the success of the plant production. For this reason, the plants were uprooted at the end of the vegetation period and the values concerning their root growth were measured. The highest RFW value (267.392 g) was obtained by the gerbera plants nourished with the 5th NSF. As a matter of course, high RDW was expected from the 5th NSF which has the highest RFW and this expectation (72.257 g) was fulfilled. The RLs measured on the gerbera plants were changed between 38.75 and 53.03 cm. The highest RL, as it is in the other parameters, was achieved with the 5th NSF, in which all fertilizers that could be required by the plants, were applied to substrate at the beginning of the vegetation period. Again, it was the 5th NSF that yielded the highest number of roots, which was twice as much as those of other formulations.

DISCUSSION

When the results of many researches concerned with the effects of the soilless culture on flower yield are considered, one can conclude that the flower yield and plant growth changed according to nutrient solution content and substrate, and the plants had better growth performances in soilless culture (Moltay et al., 1998; Issa et al., 2001; Savvas et al., 2003; Özzambak and Zeybekoğlu, 2004). At the same time, the style of applying the solution to the plants, such as reusing the solution or not, may cause an increase or reduce the yield and quality in culture (Zekki et al., 1996). Savvas and Gizas (2002) mentioned that the continuous reuse of the drain solution resulted in a slight but significant reduction of yield and quality of gerbera. Therefore in this research, open soilless culture system was preferred to use for applying the nutrient solutions. This study is of great importance as it provides a ground for comparison between available NSFs and recently developed NSFs used with different species which can also be used for plant nutrition in gerbera cultivation. In researches conducted on gerbera production for different purposes, generally only a nutrient solution was used or effect of some nutrient elements on plant growth was analyzed (Ferrante et al., 2000; Fiorenza and Paradiso, 2000; Issa et al., 2001; EunJoo et al., 2001; Savvas and Gizas, 2002; Sujatha et al., 2002; Savvas et al., 2003). Mineral nutrition has specific and essential functions in plant metabolism. Depending on the volume of requirement for a given nutrient, the nutrient is referred to as either a macronutrient or a micronutrient (Marschner, 1995). The content of the NSFs used in this research played a crucial role in flower yield and quality of gerbera plants. In this study, flower yield of gerbera's significantly differed according to the NSFs. Maximum cut flower yield per plant was obtained from the 5th NSF. Cut flower yields as obtained in other NSFs were approximately half or less than half of the yield obtained by the 5th NSF. Except for the 3rd NSF, instead of using approximately the same amount of N, P and K in NSFs applied to plants rhizosphere of gerbera plants, the flower yield was highest in the 5th NSF. Also, higher qualified flower yield from the 5th NSF can be associated with application of all macro and micro nutrient elements at the beginning of the vegetation.

Assuredly, it was thought that this was attributable to the healthy vegetative growth of gerbera plants because of the application of total nutrient elements at the beginning of the vegetation period. While Hoagland's nutrient solution is successfully used in many plant varieties, (Shi et al., 1993; Viti and Cinelli, 1993; Coetzer et al., 1994; Teragishi et al., 1998; Sotiropoulos et al., 1998; Teragishi et al., 2000; Sotiropoulos et al., 2003; Doncheva et al., 2006; Saqib et al., 2006), in this study, this nutrient solution (1st) showed an unexpectedly unfavorable result when compared to the 5th NSF. The N concentration of the 1st NSF was greater than the other solutions used in this research. Nitrogen is an essential element that has profound effects on plant growth, yield, and quality. The form of supplied nitrogen affects plant growth and yield in both soil based and soilless grown crops (Forde and Clarkson, 1999). Nitrate and ammonium are the major sources of inorganic nitrogen for fertilization of plants. As a source of N, a kind of chemical fertilizer which consists of NH_4 and NO_3 was used. But, under such conditions; N is mainly taken up as NH_4^+ rather than as NO_3^- (Forde and Clarkson, 1999), in this trial, N is supplied from the fertilizers which consist of mainly NH_4^+. Nevertheless, when the ammonium concentration in the external solution is very high, thus stimulating intensive nitrification, the root growth may be additionally suppressed due to lack of O_2, which restricts root respiration (Savvas et al., 2003). As a result of that, as given in Table 4, the flower yield was not very satisfactory in the 1st NSF, and this result may be related to the negative effect of N sources used as ammonium.

Although, Marschner (1995) reported that nitrogen alerts plant composition much more than any other mineral nutrient, the effect of N dosages on plant growth are not stable in this study. Although, the 1st NSF (210 mg L^{-1} N level) was expected to produce the best results for plant growth such as NDP, PFW, RFW, RDW, RL, NR, best results for quality such as FHD, FSUD, FSFW and highest yield according to N dose, the highest values were obtained from the plants nourished with the 5th NSF in which 150 mg L^{-1} N was used. In addition, as it was in the 5th NSF, an increase would be expected in the yield of the flower stalk with increase in the number of the daughter plant. However, although the lowest value of NDP was taken as a basis in the 2nd NSF (0.7/plant) (Table 7), this NSF came second after the 5th NSF in terms of the CFY (Table 4). This is considered to be associated with the possibility that the amount of phosphorus was higher in the 2nd NSF, in comparison to the other NSFs. It is because phosphorus is estimated to have impact on the formation of flower bud. Another nutrient solution that was used in the study and failed to produce successful results was the 3rd NSF. The analysis on the formulation revealed that N and P doses used in the formulation of this nutrient solution was lower than those used in other NSFs (respectively 50 ppm N and 26 ppm P). CFY per plant in this application was 13.67 and remained at the end of the list. This is thought to be attributable to the poor vegetative growth of gerbera plants. However, formation of daughter plant and the fresh weight of the gerbera plants observed in this treatment remained at very low values (Table 7). This may be attributable for the low dosages of N and P. As reported by Marschner (1995), "under phosphorus deficiency shoot growth is much more depressed" and "in contrast to shoot growth, root growth is much less inhibited under phosphorus deficiency, leading to a typical decrease in shoot-root dry weight ratio".

However, an examination on Table 7 shows that the 3rd NSF yielded the lowest value of fresh weight of gerbera plants in comparison to the other NSFs, while it yielded root growth better than those of the 1st, 2nd, and 4th NSFs, though not as good as the one yielded by the 5th one. In soilless agriculture, particularly in long production periods such as 10 to 11 months, the objective is to ensure increase in flower yield and quality by providing strong root and stem growth. Great attention should be paid on issues such as Ec and pH modification in the sensitive substrate, N-P-K balance and Ca-K, N-K, K-Mg etc. balance in the nutrient solution. The outcomes obtained on K and P content in all nutrient solutions used in this study are in harmony with what Savvas and Gizas (2002) stated.

In our study, the lowest flower yield per plant was produced by the 3rd NSF which includes the lowest level of K and P. Thus, Savvas and Gizas (2002) recommended increase in the relative K, P and Mn supply and correspondingly decrease that of Ca, Mg and SO_4 to optimize the nutrient status in the root environment of gerbera plants grown in closed hydroponic systems with reference to the ratios applied in open systems. However, we found significant differences between the 5th and 1st NSFs in terms of CFY per plant, although the same amounts of K and P was used. Similarly, when we compared the 5th NSF and 4th NSF, it was found that flower yield of the 4th NSF, which included higher amounts of K and same amount of P was lower than that of the 5th NSF. This may be attributable to the differences of the amounts of nitrogen and the fact that the nutrients were applied totally as basic fertilizer at the beginning of the vegetation period.

An overall analysis on all quality standards covered by the study for the purpose of determining the quality features of the flowers revealed that the best results were obtained with the 5th NSF, while worst outcomes were produced by the 3rd and 4th NSF. Although, stalk lengths of flowers, which is the most important one of these quality criteria, did not show statistically significant differences. The flowers which had the shortest stalk lengths were obtained from the 4th NSF, although it contained the same amount of N with the 2nd NSF in which solution that the longest stalks were obtained and this was thought to be attributable to the effect of the nutrients other than N. As for FHD, which is another important quality criteria, it was seen that there were statistically significant differences among the outcomes of the NSFs and it should not be forgotten that the FHDs are generally a typical feature of varieties. An analysis of Table 1 in terms of the amount of P and K used in the formulations reveals that the doses used in 1st and 5th NSFs were the same, and varied between 66 to 277 ppm in other solutions; particularly, K amount was significantly lower in the 3rd NSF (66 ppm) in comparison to the other solutions.

It is natural to have the weakest flower stems in the 3rd NSF in terms of quality characteristics considering that P is especially influential on quality. Table 6 shows that the quality features of the flower stalks produced by the 3rd NSF, particularly the thickness of flower stalks and FSFW, were poorer than those of the other NSFs. Furthermore, vaselife of the flowers harvested from the 4th NSF comprising higher amount of potassium was longer, though statistically insignificant, than those of the other applications and this significant difference was attributed to the fact that amount of dry substance on the flower stalks was high. As it is well-known, high amount of dry substance is a significant factor affecting the resistance of the flower stalks.

The findings of the present study showed that the dry weights of the flower stalks grown with the 4th NSF comprising a higher amount of potassium were higher than those grown with other NSFs. Therefore, highest FSDW and VL values in gerbera plants cultivated with the 4th NSF containing the highest K content among the NSFs used in the trial puts forward that K is an important nutrient for quality matters. As mentioned before, the purpose of the present study is to establish an efficient and abundant nutrient solution formulation for gerbera production in soilless culture. Findings of the study highlighted the importance of plant nutrition in gerbera production and the fact that plants show different reactions to different nutrient solutions with different contents. Consequently, the 5th NSF, in which macro and micro nutrient elements needed by gerbera plants during the whole vegetation period was applied at the beginning of the production period, was determined to be the best formulation. “Hoagland”, “Hewitt” and “Steiner” nutrient solutions, which are used in the production of many plant species in soilless culture failed to offer satisfactory results in this study. Furthermore, the flower yields which were obtained through production in soil (Moltay et al., 1998) and the ones obtained in this study indicated that soilless agriculture is a better choice. Flower yields reported by different researchers is approximately 5.5 to 40 in number (Moltay et al., 1998; Özzambak and Zeybekoğlu, 2004) for production in soil-based agriculture, while it reaches 75 to 80 per plant in soilless agriculture (Maloupa and Gerasopoulos, 1999). However, with the use of soilless agriculture, attention should be paid to the nutrition of the plant and the solution formulation which is the best for the species should be chosen carefully. It is because each plant species and varieties need different basic contents of nutrients.

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