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Nitrogen and Potassium Fertility and Plant Populations Influence Field Production of Gerbera

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Abstract. **Gerbera seedlings *(Gerbera jamesonii* H. Bolus Ex. Hook F.) 'Florist Strain Yellow' were planted on drip-irrigated, plastic-mulched beds at 24,000, 36,000 or 72,000 plants/ha. Nitrogen and potassium fertilizers at 55, 110, or 220 kg·ha^{-1} were factorially combined with populations. In the 1st year of a 2-year study, the number of marketable flowers increased as N and K increased to 110 kg·ha^{-1}, but as N and K were increased to 220 kg·ha^{-1}, cull production increased. In the 2nd year, marketable and cull yields increased with N rate to 220 kg·ha^{-1}; K did not affect yield. As populations increased from 24,000 to 72,000 plants/ha, marketable and cull flower production increased in both years. Flower size and quality were unaffected by plant populations. Nitrogen and potassium fertility did not affect flower size, quality, or vase life in either year.**

The majority of Gerbera cut flowers are grown in temperate zones, such as the Netherlands, in heated greenhouses and exported to the United States. The climate in coastal South Carolina is tropical to subtropical in summer and subtemperate in winter. Gerbera daisies do not reliably overwinter outdoors in temperate climates, but overwinter without significant loss in subtemperate areas. Unprotected field production of Gerbera daisies may be possible in coastal South Carolina.

Fertility requirements for field production of Gerberas are not fully known. In Florida, ground beds are fertigated through drip tubing with 0.8 to 1.2 kg of 18N-6P-12K per 30 m^2 with an additional application of N and K at each watering (Behnke, 1985). Kamel et al. (1977) found that a ratio of 2 N: 4 P: 1 K increased flower yield and that as N, P, and K rates increased, stem diameter and inflorescence weight increased. Soils in the coastal area of South Carolina are extremely high in P; hence, crops can be expected to respond to N and K. Thus, determination of fertilizer requirements for Gerbera cut-flower production is necessary for successful commercial production of this crop in coastal South Carolina.

Little information is available concerning spacing requirements for field production of cut flowers. Since costs and returns must be figured on an area basis, the greatest number of stems per area would be more profitable and efficient as long as quality of flowers is not sacrificed (Perry, 1989). Recent research described the influence of spacing on field-grown perennial crops, such as *Achilles* 'Carnation Gold', *Physostegia virginiana* L., *Liatris pycnostachya,* and *Salvia leucantha* Cav. (Armitage, 1987) and *Achillea filipendulia* and *Liatris spicata* (Perry, 1989). Behnke (1985) provided limited guidelines for protected field production of Gerberas and recommends using wide beds (75 to 105 cm) with either two or three rows of plants per bed with rows spaced 2.5 to 30 cm apart. Tesi (1977) suggested that 16 plants/m^2 be used for high yields for Gerberas grown on greenhouse soil benches. We found no reports detailing optimum plant populations for unprotected field production of Gerberas. Thus, the objectives of this study were to determine the effects of plant population and N and K fertility levels on quality and yield of field-grown Gerbera cut flowers.

'Florist Strain Yellow' (George Park Seed, Greenwood, S.C.) was selected for study. A survey of local retail florists indicated that the yellow-flower type is the most popular color. Additionally, a solid color flower type is more appropriate to study than mixed color cultivars due to less variation among plants. Gerbera seedlings were grown in Speedling cell flat size 150 (31 cm^3) in a commercial soil medium (Terra-Lite, Redi-Earth Peat-Lite Mix, W.R. Grace, Lexington, Mass.) for 12 weeks in a greenhouse. The seedlings were fertilized three times weekly with solutions of (in mg·liter^{-1}) 40 N, 18 P, 35 K.

The study was a 3 × 3 × 3 factorial consisting of three levels of N and K, each at 55, 110, and 220 kg·ha^{-1} and densities of 24,000 (low), 36,000 (medium), and 72,000 (high) plants/ha to produce 27 unique treatments. Sulfur-coated urea and K_2SO_4 were used as the N and K sources, respectively. Separation of the effects of K from sulfate were not possible. Plant population treatments were achieved by altering in-row spacings between plants to 45, 30, or 15 cm for low, medium, and high plant populations, respectively. Each plot was 3.7 m long and contained two rows separated by 30 cm on beds 1.8 m apart. Field plots were planted 13 Apr. 1987 on a Yauhanna loamy fine sand, an Aquic Hapudults. Plots were replicated three times and arranged in a randomized complete-block design.

Soil tests indicated the presence of (in kg·ha^{-1}) 2.2 NO_3-N, 231 P, 58 K. We considered N and K to be very low and deficient, but considered P to be very high. Therefore, N and K fertility studies in this soil were appropriate. Iron chelate (Sequestrene 330) was broadcast-applied over the bedded field at 5.5 kg·ha^{-1} to prevent iron chlorosis. In 1987, fertilizer treatments were applied with a Scott's broadcast lawn spreader and incorporated 5 cm deep with a Lilliston cultivator. Methyl bromide was injected into the beds and then bi-wall drip irrigation (15 mil; 0.04 mm) was buried 5 to 8 cm deep down the center of beds. White-on-black plastic mulch (1.5 mil; 0.004 mm) was laid white side up. Plots were replicated three times and arranged in a randomized complete-block design. Standard commercial pesticides were applied weekly. Irrigation was applied at 15% moisture depletion as measured by tensiometers.

In 1988, the plastic mulch was removed and the crop grown on bare ground. Identical fertilizer treatment rates were applied with a Planet Junior planter as a band down the center of the beds on 29 Feb. The fertilizer was buried 5 cm deep. New drip tubing was buried in the center of the beds 5 to 8 cm deep. Oryzalin (3,5-dinitro-N^4, N^4-dipropylsulfanilamide) at 4.4 kg·ha^{-1} was applied over-the-top (preemergence to the weeds) and incorporated with 1.3 cm of overhead irrigation.

Completely opened flowers were harvested twice weekly from 0730 to 0930 HR. Harvest in 1987 began 25 May and terminated 8 Oct.; in 1988, the harvest began 11 Apr. and terminated 24 Oct. The number of marketable and cull flowers was recorded. Cull flowers included flowers with at least one of the following defects: undersized (diameter <3.8 cm); diseased; moderate insect damage; spindly, wilted, or necrotic petals; or contorted or short stems (length <31 cm). Four randomly selected flowers per plot from each replication were harvested to determine flower size and quality on 15 June, 7 July, and 8 Oct. 1987 and 26 May and 30 Aug. 1988. Flower size and quality data included flower center and overall flower diameters, stem length, stem diameters at the stem cut and also directly below the flower, flower and stem fresh weight, and vase life. For vase life determinations, four flowers per plot from each replication were cut to a 31-cm maximum stem length and immediately placed in vases with Floralife floral preservative (Floralife, Chicago) at 9.5 g·liter^{-1} and then placed indoors under continuous, cool-white, fluorescent lights at room temperature (24 to 27C). Days to appearance of a major market defect, such as bent neck, necrotic petals, or

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Table 1. Influence of N, K, and plant populations on Gerbera marketable (M) and cull (C) flower production[z] in 1987 and 1988.

Main effect	Flowers/ha (1000s)–1987[y]								Flowers/ha (1000s)–1988							
	Early season		Midseason		Late season		Overall		Early season		Midseason		Late season		Overall	
	Flower quality								Flower quality							
	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C
N(kg·ha^{-1})																
55	48.5 a	54.5 b	7.4 a	31.9 b	20.8 b	59.6 b	76.7 b	146.1 c	37.0 a	30.3 a	67.2 c	61.9 c	21.6 c	29.9 a	125.7 c	122.0 c
110	52.5 a	60.6 b	9.9 a	35.8 b	31.5 a	72.5 a	92.9 a	168.9 b	48.5 a	35.7 a	91.9 b	80.6 b	33.4 b	28.6 a	173.8 b	145.0 b
220	54.7 a	74.6 a	8.9 a	41.6 a	32.5 a	80.9 a	96.2 a	197.2 a	44.0 a	38.0 a	114.4 a	119.0 a	45.8 a	33.2 a	204.2 a	190.0 a
K(kg·ha^{-1})																
55	44.6 c	67.1 a	8.6 a	39.0 a	26.1 a	73.9 a	79.4 b	180.1 a	38.8 a	31.4 a	81.0 a	94.0 a	30.1 a	29.2 a	149.9 a	154.7 a
110	53.0 b	64.3 a	7.6 a	38.5 a	30.7 a	72.7 a	91.4 a	175.6 a	48.4 a	37.6 a	100.3 a	86.0 a	37.9 a	29.4 a	186.6 a	153.0 a
220	56.9 a	58.5 a	10.0 a	31.7 b	28.0 a	66.3 a	95.0 a	156.6 b	42.3 a	35.0 a	92.1 a	81.4 a	32.8 a	33.0 a	167.1 a	149.5 a
Plants/ha																
24,000	29.6 c	44.1 c	5.9 b	25.2 c	20.4 b	54.0 c	55.9 c	123.4 c	36.5 b	29.0 b	90.7 a	85.1 b	30.3 a	30.3 a	157.6 b	144.3 b
36,000	46.2 b	57.9 b	8.9 a	33.8 b	23.3 b	69.9 b	78.5 b	161.8 b	35.2 b	32.5 b	84.6 a	99.4 a	33.0 a	34.2 a	152.7 b	166.2 a
72,000	78.7 a	87.8 a	11.5 a	50.2 a	41.0 a	89.0 a	131.4 a	227.1 a	57.8 a	42.5 a	98.2 a	77.0 b	37.4 a	27.1 b	193.4 a	146.7 b
Source of variation[x]																
Replication	18**	5**	6*	2	3	1	11**	2*	12**	10**	14**	2*	10**	0	16**	4*
N	1	11**	3	14**	10**	13**	4**	13**	3	4	18**	54**	37**	4	18**	43**
K	3**	2	3	10**	1	2	2*	3*	2	3	3	2	3	3	3	0
N × K	1	1	1	1**	3	4	0	1	4	3	1	1	1	2	1	2
Pop.	52**	52**	17**	10**	29**	33**	53**	56**	17**	15**	2	7**	3	9	5*	5*
N × Pop.	3	3	8	3	3	4	4*	3*	2	1	0	2	1	5	1	4
K × Pop.	3	1	2	1	5	7*	3	3	1	1	0	1	3	3	1	2
N × K × Pop.	3	5	10	7	11*	2	4	2	8	4	10	4	5	5	9	2
Error	16	20	50	52	35	34	19	17	51	59	52	27	37	69	46	38

[z]Mean separation within main effect by LSD at $P = 0.05$.
[y]Early season, 1987 = 28 May to 27 July; midseason, 1987 = 3 to 27 Aug.; late season, 1987 = 2 Sept. to 28 Oct.; early season, 1988 = 11 Apr. to 30 May; midseason, 1988 = 3 June to 29 Aug.: and late season, 1988 = 3 Sept. to 24 Oct.
[x]Percentage of total sum of squares attributablc to each factor in the analysis of variance.
*,**Significant at $P = 0.05$ or 0.01, respectively. Values not followed by asterisks arc nor significant at $P = 0.05$.

wilted petals, were counted. Vase life was determined three times in 1987 (15 June, 7 July, and 8 Oct.) and once in 1988 (26 May).

Plant tissue elemental status was determined at the end of each cutting season in both years while plants were still actively growing. Six to 10 leaf samples of the youngest unfurled leaves were removed from each plot per replication on 23 Oct. 1987 and 13 Oct. 1988 to detect if fertilizer treatments still affected leaf elemental composition at season's end. Leaf tissue was dried at 65C for 24 hr and ground. The N. P, K, Mg, Ca, and NO_3-N contents were determined by the Clemson Univ. Agricultural Chemical Services Dept., Clemson, S.C.

Population effects. In the 1st year, >50% of the variation in both early and overall season marketable and cull yields was attributable to population treatment effects (pooled over all N and K rates) (Table 1). Most of the variation in mid- and late-season yields was attributable to uncontrolled error. As populations increased from low to high densities, early and overall yields increased. Marketable yields had not levelled off at the highest density evaluated. In the 2nd year, a lesser, but significant, amount of variation in early yields was attributable to population effects. Yield of marketable and cull flowers was equivalent for the low and medium densities, but early yields increased significantly with the higher densities. Mid- and late-season marketable yields were unaffected by population in 1988, but when pooled over all harvest periods, yield of marketable flowers was higher with 72,000 plants/ha than at lower populations. Overall cull flower production was the same for the low and high populations, but significantly higher with medium populations.

Plant populations in the 1st year affected leaf elemental content much less than N or K fertilizer treatments (Table 2). As populations increased from moderate to high densities, NO_3-N content decreased. Population treatments had very little or no effect on the percentage of N, K, Mg, and Ca content. The percentage of P in leaf tissue was not affected by any fertility or population treatments in 1987 (data not shown). In the 2nd year, as populations increased from moderate to high densities, the percentage of N decreased. Nitrogen content was similar for low and medium densities. Leaf P decreased as population density increased. As populations increased from low to medium densities, the K content decreased without further significant response at the highest plant population. Population density did not affect Ca or NO_3-N content. None of the experimental treatments affected the Mg content in the 2nd year's experiment (data not shown).

Gerberas can be planted at high densities of at least 72,000 plants/ha without losses in yield or quality. The better efficiency of production per unit area of space with higher plant population still warrants the use of high plant densities, even though cull production increases. Higher plant populations than those evaluated may further enhance yields, but higher fertilizer rates would have to be increased concomitantly.

Nitrogen effects. The N requirements to produce high yields of Gerberas differed in relation to the maturity of the field planting. Nitrogen fertility in the 1st year (pooled over all K and population treatments) affected yields but to a lesser extent than populations (Table 1). Early and midseason marketable yields were unaffected by N rate, but late and overall seasonal yields were enhanced by N fertility. As N was increased from 55 to 220 kg·ha^{-1}, overall and cull yields increased. In contrast, marketable yield increased with N rates up to only 110 kg·ha^{-1}. In the 2nd year, N fertility was more efficacious in increasing yields later in the season. As N rate was increased from 55 to 220 kg·ha^{-1}, midseason, late-season, and overall marketable yields increased. Production of cull flowers in midseason and overall increased as N rate was increased from 55 to 220 kg·ha^{-1}, but early and late-season cull production was unaffected by N rate. Although high levels of N are necessary to increase marketable yields, cull production also tended to increase with N rate.

Major portions of variation in the elemental composition of leaf tissue in the 1st year were attributable to N main effects and to unexplained error (Table 2). As N fertilizer rate was increased from 5.5 to 220 kg·ha^{-1}, N and NO_3-N in the leaves increased. The K, Mg, and Ca concentrations increased as N rate was increased up to 110 kg·ha^{-1}. In 1988, N fertility was the major source of variation in leaf elemental content of all

Table 2. Influence of N, K, and plant populations on Gerbera leaf tissue nutrient content[z] at the end of the harvest season in 1987 and 1988.

	Nutrient concn									
	N (%)	K (%)	Mg (%)	Ca (%)	NO_3-N ($mg\cdot kg^{-1}$)	N (%)	P (%)	K (%)	Ca (%)	NO_3-N ($mg\cdot kg^{-1}$)
N($kg\cdot ha^{-1}$)			*1987*					*1988*		
55	1.29 c	1.34 b	0.32 b	0.67 b	44 b	1.62 c	0.25 c	1.48 c	0.42 a	29 c
110	1.38 b	1.61 a	0.40 a	0.82 a	69 b	1.77 b	0.28 b	2.49 b	0.38 b	54 b
220	1.53 a	1.52 a	0.41 a	0.82 a	164 a	2.20 a	0.34 a	4.15 a	0.37 b	97 a
K($kg\cdot ha^{-1}$)										
55	1.48 a	1.42 b	0.38 a	0.73 a	118 a	1.93 a	0.29 a	2.39 b	0.40 a	77 a
110	1.36 b	1.42 b	0.39 a	0.79 a	93 a	1.88 ab	0.29 a	2.76 a	0.38 a	56 b
220	1.36 b	1.62 a	0.37 a	0.80 a	66 a	1.79 b	0.29 a	2.96 a	0.39 a	47 b
Plants/ha										
24,000	1.42 a	1.50 ab	0.39 a	0.80 a	119 a	1.98 a	0.30 a	2.96 a	0.40 a	60 a
36,000	1.43 a	1.40 b	0.38 a	0.71 a	109 a	1.89 a	0.29 b	2.67 b	0.38 a	62 a
72,000	1.35 a	1.57 a	0.37 a	0.81 a	49 b	1.72 b	0.27 c	2.39 b	0.39 a	57 a
Source of variation[y]										
Replication	13**	12**	1	6	3	2	0	1	3	1
N	26**	13**	19**	10**	21**	53**	73**	66**	9*	37**
K	8**	10**	1	2	3	3*	0	3*	0	7*
N × K	7**	5	1	1	6	0	0	1	3	4
Pop.	4	5*	0	4	7*	10**	7**	4**	0	0
N × Pop.	3	1	7	4	7	5	0	5**	6	5
K × Pop.	2	3	10	14	1	1	0	2	6	0
N × K × Pop.	6	9	8	4	4	2	7*	6*	16	3
Error	31	42	53	55	48	24	13	12	57	43

[z]Mean separation within main effect by LSD at P = 0.05.
[y]Percentagc of total sum of squares attributable to each factor in the analysis of variance.
*,**Significant at $P = 0.05$ or 0.01, respectively. Values not followed by asterisks are not significant at $P = 0.05$.

treatment effects. As N fertilizer rate was increased from 55 to 220 $kg\cdot ha^{-1}$, the N, P, K, and NO_3-N contents increased, but Ca content decreased.

Potassium effects. Potassium fertility was important in improving earliness of yield in the 1st year. Potassium level in the 1st year (pooled over all N and population treatments) affected yield significantly, but to a lesser degree than population or N effects (Table 1). Early season marketable yields increased as K rates were increased from 55 to 220 $kg\cdot ha^{-1}$, but mid- and late-season marketable yields were unaffected by K rate. Overall marketable flower yield was higher with K at 110 than 55 $kg\cdot ha^{-1}$ with no further increases at 220 $kg\cdot ha^{-1}$. Increasing K rate to 220 $kg\cdot ha^{-1}$ decreased cull production. In the 2nd year, K fertility levels did not affect yield at any harvest period.

Although K seemed of little value in enhancing yield and quality in the 2nd year, tissue analysis indicated that K content in the leaves was higher with increasing K fertilizer rates in both years (Table 2). Potassium fertility generally had less effect on leaf tissue elemental composition than N fertility in both years. In the 1st year, the percentage of K in the tissue was higher with K at 220 $kg\cdot ha^{-1}$ than at the lower rates. Leaf N, but not NO_3-N, was higher at 110 kg K/ha than at 55 $kg\cdot ha^{-1}$ without a further increase at the highest rate. The Mg and Ca contents in the leaves were unaffected by K fertility. In the 2nd year, K content increased only as K fertilizer rate was increased from 55 to 110 $kg\cdot ha^{-1}$. Conversely, as K fertilizer rate increased to 220 $kg\cdot ha^{-1}$, the N content decreased. The P and Ca leaf concentrations were unaffected by K fertilizer treatments.

In our study, increasing the K fertility rate decreased the N concentration in both years and NO_3-N content in the 2nd year in leaf tissues. The response of K uptake by crops may depend on the level of N nutrition, since N fertility is only fully used for crop production when K supply is adequate (Gartner, 1969; Heathcore, 1972). Potassium has a role in the uptake and/or translocation of NO_3-N within plants (Koch and Mengel, 1977). Although not important in yield enhancement in the 2nd year's study, we considered at least 220 $kg\cdot ha^{-1}$ to be necessary to sustain plant growth.

Flower size, vase life, quality, and major market defects were affected negligibly by fertility and population density during the course of the harvest season in both years (data not shown). Most of the variation in flower growth and quality variables was due to unexplained error. The major quality factor affecting marketability of Gerberas was short stem lengths. The average stem length of all pooled treatments was 27 cm in the 1st year and 34 cm in the 2nd. Stems up to 60 cm are more desirable in the floral trade. Visual observations of this field plot in the 3rd year indicated that stem length increased further. Gerbera field production may continue into a third year since yield and quality still were acceptable.

Yield is a function of plant stand establishment. Stand counts from the initial planting were compared IO those at the experiment's termination to determine if any of the fertility or population treatments were particularly susceptible IO stand loss (data not shown). Nitrogen and potassium fertilizers had no effect on stands in our soils with P levels as high as 231 $kg\cdot ha^{-1}$. Final stands were significantly higher the higher the initial plant populations. Stands decreased 11.4%, 85, and 7.2% from Spring 1987 to Fall 1988 in the high, medium, and low populations, respectively.

In general, marketable yields were 76% higher in the 2nd than the 1st year. The quality of the 1st year crops was inferior to those of the 2nd year. In the 1st year, 34% of the yield was marketable and 66% was cull. In the 2nd year, 51% of the yield was marketable and 49% cull. Thus, Gerbera should be considered a perennial crop with greater yield potential as the age and maturity of the planting increases.

Based on this 2-year study, at least 110 kg N/ha and 220 kg K/ha are required for high cut-flower yields in the lst year of establishment. In the 2nd year, at least 220 kg each of N and K/ha are required for high yields. Split application of N-K fertilizers may be more efficacious in improving yields to lessen the reduction in essential elements by season's end.

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