Effects of Nitrogen and Potassium Fertilization on Infection of Florists' Carnation by *Gibberella zeae*

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ABSTRACT

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Carnation plants growing under commercial glasshouse conditions received three levels of nitrogen and three levels of potassium fertilization. Levels of nitrogen and potassium were monitored by soil tests and by foliar analysis. Cut stubs left from crop harvest were inoculated with *Gibberella zeae*, causal agent of Fusarium stem rot. Incidence and severity of disease were determined 60 days after inoculation. As levels of balanced nitrogen and potassium were increased from low to intermediate to high, incidence of infection increased significantly (25, 35, and 47%, respectively). There were many more severe infections (19%) in the high-nitrogen + low-potassium treatment than in any other treatment (2.3–3.5%).

Fusarium stem rot and stub dieback of florists' carnation (*Dianthus caryophyllus* L.) in the eastern United States is caused largely by *Gibberella zeae* (Schw.) Petch (anamorph: *Fusarium graminearum* Schw.) (6). Fusarium stem rot is an endemic disease capable of causing serious losses (3,6,13). The degree of infection is affected by both host and environmental factors (10–12).

Levels of fertility are known to affect plant susceptibility to infection and colonization by plant pathogens (4). Nitrogen levels in particular are known to be associated with disease responses. Forms of nitrogen, oxidized or reduced, have also been shown to affect disease in some systems (4). Elevated potassium levels reduce many diseases and high potassium levels may offset or reduce the effects of high nitrogen (4). The mechanism for these disease responses to fertility is unknown except in a few cases (4).

Glasshouse florists' carnations are grown under intensive management and at high levels of fertility (2,5). Under such conditions, effects of fertility levels on disease may be enhanced, causing greater losses than might be seen in field crops. Our preliminary report (9) associated nitrogen and potassium with disease intensity. In this study, we report the effects of levels of the two elements on infection of carnation by *G. zeae* and the resultant disease.

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MATERIALS AND METHODS

Growing conditions. The experiment was done in a glasshouse providing daytime ventilation above 18 C and nighttime heating to maintain a minimum of 10 C. During the first part of the growing period, temperatures regularly exceeded these values, but during the incubation period after inoculation, these temperature limits were maintained. A raised bed 0.9 m wide × 21 m long × 0.4 m deep was filled with a soil mixture composed of equal parts of sphagnum peat, sand, and loamy soil. On the basis of a preplanting soil test, superphosphate was added to provide 4–5 mg/kg of phosphorus and ground limestone was added to set the pH at 6.0. Fritted trace elements (Peters No. 555, containing Fe, Mn, Zn, Cu, B, Mo, and S) were thoroughly mixed with the soil. The soil-filled bench was pasteurized at 85 C for 4 hr using aerated steam. Residual soil nitrogen and potassium levels before planting were 8 and 7 mg/kg, respectively. The bench was divided into 16 compartments by watertight partitions; each compartment had its own free drainage and received a single fertilizer treatment. There were five treatment combinations and three replicates. The 16th compartment was an uninoculated control fertilized at the recommended (intermediate) rate.

Soil and foliar analyses. Complete soil tests were made monthly on each compartment for nitrogen, potassium, phosphorus, calcium, pH, and total soluble-salt levels. Corrective measures were applied to keep levels of calcium, pH, and soluble salts within recommended levels (i.e., calcium = 100 mg/kg, pH = 6.0–6.5, and soluble salts $< 100K \times 10^{-5}$) (5).

Complete spectographic foliar analyses were made four times during the study by flame spectrometry (7,8) of each treatment. The first analysis was done on leaves from rooted cuttings just before planting, the second 42 days after planting, the third 130 days after planting, and the fourth after 210 days, when disease ratings were taken.

Culture. Rooted carnation cuttings of three cultivars (Improved White Sim, Atlantis, and U. Conn. Sim No. 1) were planted on 16 July at a spacing of 20 × 20 cm. There were 63 rooted cuttings per compartment, 21 of each cultivar. After planting, cultivars were not separated, so all data are a balanced composite of the three.

All plants were pinched 6 wk after planting so they would produce an average of three or four flower stalks each. Flower buds showed color in early December. On 14 December, all stems were cut off 0.3 m above the soil line and inoculated with *G. zeae*. After 60 days, disease data were taken.

Inoculum and inoculation. The isolate used in these studies was R-762 of the Fusarium Research Center (Pennsylvania State University, University Park) collection. Pathogenicity of this isolate was maintained by continual isolation from rapidly developing lesions on inoculated carnation plants (11), and a freshly isolated culture was used for inoculum production. Inoculum of *G. zeae* was a suspension containing 10,000 macroconidia per milliliter prepared by washing spores from 10- to 11-day-old cultures grown in petri dishes on potato-dextrose agar at 24 ± 2 C and 15 cm from a 40W near-ultraviolet light (Sylvania blacklight tube no. F40-BLB). A 10-μl droplet was applied to each cut carnation stem.

Fertilizer treatments. Fertilizer solutions were prepared to supply three levels of nitrogen and three levels of potassium in five combinations: 1) N and K at 200 mg/L, 2) N and K at 40 mg/L, 3) N and K at 400 mg/L, 4) N at 40 mg/L and K at 400 mg/L, and 5) N at 400 mg/L and K at 40 mg/L. Treatment 1 is the recommended rate for commercial carnation production (5). All fertilizer stock solutions were prepared from reagent-grade KCl, KNO_3, and $CaNO_3$. To maintain a minimum level of 100 mg/L of calcium in the fertilizer solution, $CaCl_2$ was used as needed. Fertilizer solutions were applied

weekly from July until November and every 10 days thereafter (December through February). Application was always beyond the point of free drainage. During warm periods in July and August, supplemental watering was supplied as needed. Only nitrate nitrogen was used in these fertilizer solutions to avoid confounding effects of nitrogen form.

Disease ratings. Plants were examined for disease symptoms 210 days after planting and 60 days after inoculation. Inoculated stems were cut and the extent of lesions was determined. Necrosis of side shoots arising below the cut stubs was also recorded.

RESULTS

Fertility and analysis. Inoculation of stems was delayed until both soil and foliar analysis for nitrogen and potassium reflected the effects of the different treatments. Results of the soil test made just after inoculation clearly reflect the treatments (Table 1). The values for pH, phosphorus, calcium, and soluble salts were similar for all treatments.

Levels of elements in foliage are lower than those applied in the fertilizer solution (Fig. 1). Although the fertilizer treatments began immediately after planting, the plant tissue levels showed little effect of treatment until 130 days after planting. Nutrient levels continued to diverge during the incubation period between inoculation and harvest.

Standardization of levels of other elements was verified by the complete foliar analysis after 130 days (Table 2). Only levels of sodium, zinc, manganese, and boron differed among the treatments. The level of sodium was inversely correlated to that of potassium. The levels of zinc, manganese, and boron differed among the treatments, but no pattern could be discerned.

Levels of magnesium, iron, sodium, manganese, and boron were slightly lower and those of zinc and copper slightly higher in the final foliar analysis (210 days) than in the 130-day analysis, but the general relationship was unchanged.

Disease. Uninoculated stems showed no infection after 60 days in contrast to the typical stem rot lesions in 25–55% of inoculated stems (Table 3). As equal amounts of nitrogen and potassium fertilization increased from 40 to 200 to 400 mg/L, the incidence of infection increased from 25 to 35 to 47%, respectively. When either element was applied at the high rate (400 mg/L), the incidence was the same as at the highest balanced rate (Table 3).

The loss occasioned by stem rot consists largely of necrosis of side shoots (source of the next crop) as lesions girdle the stem below their origin (13). This type of damage was recorded separately as shoot mortality (Table 3), where incidence of lateral shoot necrosis is the number of inoculated stems with killed side shoots and not the number of such killed shoots. High nitrogen and low potassium was the only treatment that caused a significantly higher level of necrosis of side shoots (Table 3).

DISCUSSION

As levels of fertility increased from low to intermediate to high, the incidence of infection rose from 25 to 47%. Although incidence of infection increased, severity of disease as measured by shoot necrosis did not change as long as the elements were balanced. When the N:K ratio was low (0.1) or balanced (1.0), disease severity was the same as with the intermediate or low fertilizer levels, but when the N:K ratio was high (10.0), disease severity increased sixfold (Table 3). Growers of glasshouse crops are often advised to avoid unbalanced high nitrogen levels because of adverse effects on the quality of the crop (2,5). Our results indicate another reason for such caution. Disease susceptibility may increase under unbalanced high nitrogen levels. In reviewing the effects of nutrients on disease, Huber (4) reported that NO_3 nitrogen increased and potassium decreased diseases of wheat and corn caused by *G. zeae*. Actual levels of nitrogen are important and the N:K ratio is important as well. In corn infected with *G. zeae*, high N:K ratios appear to favor disease more than the same levels of

Table 1. Preinoculation analysis of soil treated weekly with various combinations of nitrogen and potassium

Treatment (mg/L)	N (mg/kg)	K (mg/kg)	P (mg/kg)	Soil test level		
				Ca	pH	Soluble salts ($K \times 10^{-5}$)
1. 200 NK	18	6	2.0	146	6.1	79
2. 40 NK	4	4	1.7	167	6.2	77
3. 400 NK	85	12	2.3	153	6.2	107
4. 40 N + 400 K	5	20	2.0	161	6.0	78
5. 400 N + 40 K	80	4	2.3	157	6.1	99

Table 2. Foliar analysis of carnation plants inoculated with *Gibberella zeae*[a]

Treatment (mg/L)	Percent by weight					mg/kg						
	N	P	Ca	K	Mg	Na	Zn	Mn	Fe	Cu	B	Al
1. 200 NK	4.03	0.56	1.8	2.87	0.41	2,720	61	620	108	13	41	66
2. 40 NK	3.03	0.60	1.8	2.57	0.35	3,680	82	605	114	17	56	65
3. 400 NK	3.83	0.63	2.0	4.10	0.40	1,800	80	702	122	16	48	66
4. 40 N + 400 K	3.00	0.62	1.8	4.60	0.32	1,730	101	744	119	16	55	68
5. 400 N + 40 K	4.30	0.70	2.1	1.93	0.46	3,820	57	691	109	14	42	74

[a] Foliar analysis samples taken 130 days after planting, 3 wk before inoculation. Each value is the mean of three replicate samples analyzed separately.

Table 3. Infection of carnation plants by *Gibberella zeae* fertilized with different levels of nitrogen and potassium

Treatment[a]			Disease incidence (%)[b]	
N (mg/L)	K (mg/L)	Inoculation	Stem lesions	Lateral shoot necrosis
0. 200	200	−	0*	0.0
1. 200	200	+	35	2.8
2. 40	40	+	25	3.4
3. 400	400	+	47	2.3
4. 40	400	+	49	3.5
5. 400	40	+	55	19.1*

[a] Nitrogen and potassium applied weekly.

[b] Percentage of plants showing stem lesions and lateral shoot necrosis. Values followed by an asterisk are significantly different from treatment 1 at $P = 0.05$ on the basis of chi-square comparisons of actual counts.

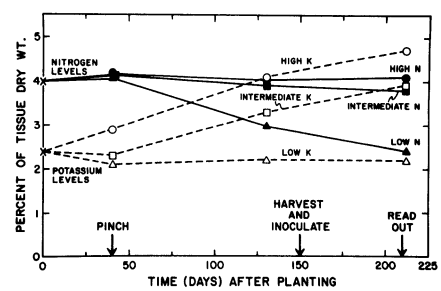

Fig. 1. Levels of nitrogen and potassium in carnation plants under different fertilizer treatments over time. Results based on tissue analaysis of foliage samples taken at planting and at three later times as indicated. Fertilizer treatments applied weekly in irrigation water: high N = 400 mg/L (treatments 3 and 5); intermediate N = 200 mg/L (treatment 1); and low N = 40 mg/L (treatments 2 and 4). High K = 400 mg/L (treatments 3 and 4); intermediate K = 200 mg/L (treatment 1); and low K = 40 mg/L (treatments 2 and 5)

nitrogen if balanced by high levels of potassium (14). In our study (Table 3), this "safening" effect of potassium was also apparent. Although incidence of infection was not different among the three high-level treatments, severity of disease as indicated by shoot necrosis was affected by the N:K ratio. Our results differ from those of Dorworth and Tammen (1), who studied the effect of stock plant nutrition on Fusarium rot of cuttings.

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