Effects of Nitrogen, Phosphorus, and Potassium Fertilization of Roses on Oldsmar Fine Sand[1]

T. W. Young[2], G. H. Snyder[3], F. G. Martin[4], and N. C. Hayslip[5]
University of Florida, IFAS, Homestead

Abstract. 'Christian Dior' and 'Happiness' roses on *Rosa fortuniana* stock, fertilized with 3 rates each of N, P, and K factorially combined, were grown for 3 years at Ft. Pierce, Florida. All fertilizer was applied at the beginning of the experiment under plastic mulch just before the bushes were planted. About 2300 lb./A of N on 'Christian Dior' and 2100 lb. on 'Happiness' produced the greatest number of flowers. Leaf N at 18 months was also maximized by 2100 lb. N. Nitrogen levels maximizing stem lengths were slightly lower. The independent effects of P were minor and low levels best, perhaps because residual soil P at start of the study was adequate. Flower production decreased with K fertilization beyond low rates, whereas stem lengths increased to a max at about 1700 lb./A. At times, various nutrient interactions were noted. 'Christian Dior' consistently yielded more flowers than 'Happiness'. With minor exceptions, 'Happiness' had longer stems.

Commercial production of roses in Florida for cut flowers and container-grown plants is almost exclusively on *Rosa fortuniana* rootstock. Better yields of flowers with longer stems and a longer period of productivity are obtained on it than on other stocks tried under local conditions (6). Only a limited amount of systematic research has been done on nutritional problems peculiar to roses on this stock. Some symptoms of malnutrition of 'Pink Frill' roses on *R. fortuniana* stock grown in sand culture have been described (4). Waters (9) grew 'Tropicana' roses on *R. fortuniana* stock on Leon fine sand with 3 levels of N and 2 levels of K in factorial combinations. Increasing N fertilization increased the number and wt of flowering stems harvested and N content of leaves. There was no significant growth response from increased K fertilization, but K content of leaves increased. The vase-life of cut flowers was not affected by the treatments.

We report effects on number of flowers and stem lengths for a period of 3 years from a single heavy application of N, P, and K at 3 levels in factorial combinations made under plastic mulch at the beginning of the experiment with 'Christian Dior' and 'Happiness' roses on *R. fortuniana* stock in the field. The primary reason for using plastic mulch was to reduce leaching losses, thereby minimizing the effect of this variable as much as practicable under conditions of the experiment. A supplemental experiment conducted in conjunction with the main experiment showed that fertilizer thus applied gave equally as good results for 18 months, or somewhat longer, as an equivalent amount of fertilizer annually, but applied bi-weekly without mulch (8).

Materials and Methods

The experiment was on Oldsmar fine sand[6] which has a spodic horizon at a depth of about 20 inches. This soil is inherently infertile, almost a builders sand. With the exception of some residual P from a previous farming operation, the mineral content was of no agronomic significance. With the combination of light, infertile sand soil, plastic mulch and a relatively shallow spodic horizon which helped retard leaching and on which sub-irrigation was practical, the growing method was virtually sand culture. Thus, results are broadly applicable.

The entire experimental area was treated with dolomitic limestone at the rate of 1 ton/A shortly before the bushes were planted. Each plot consisted of 4 bushes planted in a row at a spacing of 15 inches. Plots were separated by 7-ft unfertilized buffer zones in the row. The rows were spaced at 7 ft on beds 4 ft wide at the top, 5 ft at the bottom and 10 inches high. Both cultivars were grown with 300, 900, and 2700 lb. N; 0, 87, and 174 lb. P; and 249, 747, and 2241 lb. K per planted acre, factorially combined, using a split-plot design with varieties constituting the sub-units. Each main plot was replicated 4 times. Thus, there were 216 sub-plots of 4 plants each. The entire supply of fertilizer for the duration of the experiment was applied on November 1, 1964, just before the recently grafted bushes were planted. N was derived from ammonium nitrate, P from triple superphosphate and K from potassium chloride. Before bedding, 100 lb. N and 83 lb. K per planted acre, together with all the P and adequate Mg, Mn, Cu, Zn, B, Fe, and Mo, were applied at the soil surface in an area 8 inches wide and 5 ft long, centered along the planting row of each plot. Plant beds were then thrown up over the fertilizer by means of bedding disks and a bed press. The remainder of the N and K fertilizer was distributed evenly in a 4-inch wide band about 20 inches from the center of the bed on each shoulder adjacent to the planting area and covered with about 1 inch of soil.

After the fertilizer was placed, the plot beds were covered with 6 mil black polyethylene film, which was suitably anchored. Four-inch diam holes were cut in the film at the proper locations, and bushes planted in the soil at the holes. Methods of irrigation, weed, insect, mite, and disease control have been described elsewhere (10). As a further precaution against Zn and Mn deficiencies, the fungicides used were alternated between materials carrying these elements. Beginning in August, 1966, nutritional sprays containing Mg, Cu, Fe, B, and Mo were made monthly.

About 6 months after planting, and prior to recording harvest data, all shoots with flowers were cut back to the third or fourth full (5-leaflet) leaf from the base of the individual shoot. Flowering shoots that occurred after this were disbudded to the 1 central flower bud. Cutting of flowers for experimental data was according to the common commercial practice, which, in general, was immediately above the second 5-leaflet leaf from the base of the shoot. Harvest was twice weekly on all plants. The number of flowers per plot and their stem lengths (from cut to base of receptacle) were recorded, beginning June 1, 1965. In these harvest data, all stem lengths constitute "total flowers," and lengths above 9 inches are "commercial flowers;" those 9

[1]Received for publication August 24, 1972. Florida Agricultural Experiment Stations Journal Series No. 3974.
[2]Agricultural Research and Education Center, Homestead.
[3]Agricultural Research and Education Center, Belle Glade.
[4]Statistics Department, Gainesville.
[5]Agricultural Research Center, Ft. Pierce.
[6]Formerly classified as Immokalee f.s.

inches or less in length are culls. Harvest data were collected through August, 1967.

Soil samples were taken through the N-K fertilizer bands to a depth of 6 inches 4 times during the study. These samples were air dried, mixed, and analyzed for pH and extractable N, P, and K. Nitrate was determined in NaOAc, pH 4.8 extracts by the phenoldisulfonic acid technique (5, p. 197-201). Phosphorus was determined colorimetrically in NH_4OAc extracts by the ammonium molybdate-stannous chloride method (5, p. 141-144) and K was determined in these extracts by flame photometry (5, p. 461-464). Tissue samples were taken 3 times during the course of the study, and analyzed for N, P, and K. The first four 5-foliate leaves from below the flower bud on shoots ready for harvest were selected for sampling. After oven drying at 70°C, the micro Kjeldahl method was used for determining N (5, p. 183). Portions of the samples were wet digested in a mixed acid solution (10:4:1 mixture of HNO_3:$HClO_4$:H_2SO_4), and analyzed for P colorimetrically and for K by flame photometry. Leaf Cl was determined on selected samples, using an AOAC potentiometric titration method (3).

Using the analysis of variance (7), all harvest data were analyzed statistically by quarters (summer, fall, winter, and spring) for the 9 quarters of harvest, and for the first and second full years of harvest. In order to obtain the max information from the data the sums of squares associated with the 3 fertilizer elements were partitioned, using orthogonal polynomials, into single degree of freedom components associated with the regression relationship between fertilization rate and the response. Based on these results, the degree of the relationship was determined and the regression equations estimated (1). Each equation was then examined analytically to determine the effect of each of the 3 fertilizer elements. The effect of cultivar was included in these equations by introducing a dummy variable V which was assigned the value 1 for 'Christian Dior' and the value -1 for 'Happiness'.

Examination of stem length data showed that between 70 and 80% of both 'Christian Dior' and 'Happiness' flowers fell rather consistently into commercial classes. Therefore, for the sake of brevity in this paper, only "total flowers" (all stem lengths) are considered. A schematic diagram (Fig. 1) shows the sequence of events during the study.

Results

The most important effect of the treatments was that of N on the number of flowers (Table 1). The number of flowers of both cultivars increased with increasing N up to a max (Fig. 2). The production on 'Christian Dior' was always greater than that on 'Happiness', regardless of N level. The percentage of difference between the 2 cultivars in number of flowers increased as N increased, even beyond the point of max yield. The max number of flowers the first year was estimated to occur at about 2250 lb. N/A on 'Christian Dior' and at about 2070 lb. on 'Happiness'. This agrees well with data from the tissue analysis (Table 2) which show that the max N content of leaves from both cultivars at this time occurred at a fertilizer level of about 2100 lb. N/A. Optimum levels of N for the second year were estimated at about 2530 and 2200 lb./A for

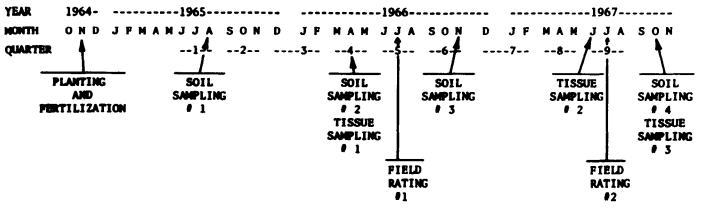

Fig. 1. Sequence of events during the study.

Table 1. Main effect means: number of flowers and stem lengths.

	No. of flowers per plant		Stem length in inches	
	First year	Second year	First year	Second year
Nitrogen				
300 lb./A	35.2	29.2	12.1	11.0
900 lb./A	48.7	40.4	12.9	11.9
2700 lb./A	58.3	51.1	13.0	12.4
	Q**	Q**	Q**	Q**
Phosphorus				
0 lb./A	47.7	40.7	12.9	11.9
87 lb./A	45.9	38.9	12.6	11.7
174 lb./A	48.5	41.1	12.5	11.8
	NS	L*	Q*	Q*
Potassium				
249 lb./A	48.6	39.6	12.2	11.3
747 lb./A	49.1	43.2	12.7	12.0
2241 lb./A	44.5	37.9	13.1	12.0
	L**	Q**	Q*	Q**
Variety				
'Christian Dior'	60.4	50.3	11.7	11.5
'Happiness'	34.4	30.2	13.6	12.1
	**	**	**	**

Statistical significance and relationships:
NS Not significant
* Significant at 5% level
** Significant at 1% level
L Linear
Q Quadratic

'Christian Dior' and 'Happiness', respectively. This increase in N level required for max yield the second year over that of the first year resulted from depletion of soil N with time, since no

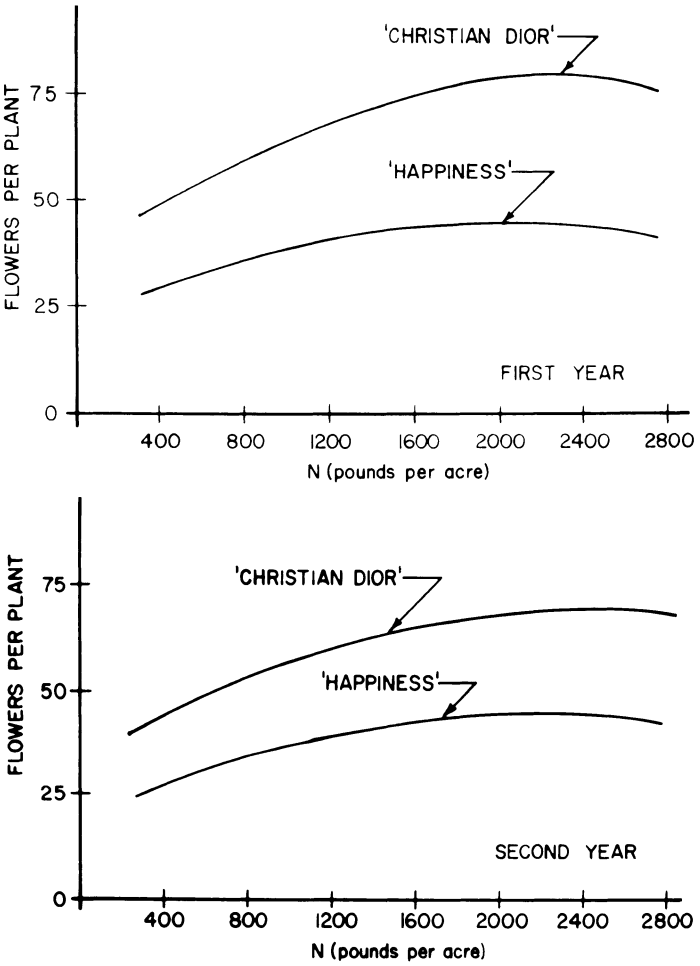

Fig. 2. Total flowers vs. N fertilization. First year calculated from equation A and second year equation B in Table 2 with P at 50 lbs./A and K at 750 lbs./A.

Table 2. Main effect means: tissue percent N at 18 months as affected by N fertilization.

Nitrogen fertilization	Tissue % N
300 lb./A	2.59
900 lb./A	2.78
2700 lb./A	2.89
	Q**
$\%N = 2.4716 + 0.0^{3}433N - 0.0^{6}102N^2 - 0.0481V$	

**Quadratic relationship significant at the 1% level.

fertilizer was applied after the initial treatment at the beginning of the experiment. For example, the average soil NO_3^- in the region of the band in the 2700 lb. N plots was 442, 164, 101, and 55 ppm at 9, 17, 24, and 35 months, respectively, following fertilization, although the rate at which N left the entire mulched bed was slower than the rate at which it moved from the band. Nevertheless, for a given N level, actual N in the soil was lower the second year than the first. It is important to note that the estimated optimum level of N for the second year is the amount of N which must be applied the first year in order to maximize second year yields. Because of the expected depletion of N it is reasonable that this value should be higher than that of 'Christian Dior' throughout the range of experimental N levels used.

While the general effect of N on number of flowers was about the same the second year as the first, the effect of K the second year depended upon the amount of P applied. The nature of this interaction, with N at 1300 lb./A, is shown in Fig. 3. At K levels giving optimum yield, increased P reduced yields. At lower and higher levels of K, the effect of P in reducing yields was less. Yields decreased at K levels greater than about the mid-point of the K fertilization range. As with N, soil K was depleted with time since no fertilizer was applied after initial treatment. Therefore, yields decreased throughout most of the K fertilization range the second year. This was consistent with data for the first year.

Since the soil samples were taken through the N-K fertilizer band, which was located over 22 inches away from the P band, P in these samples gives a measure of the residual soil P. It bore no relation to the applied P, except in samples taken at the end of the third year. Residual P, thus gauged, was around 30 lb. P/A, which is adequate for most crops. This explains why, except for its effect through the interaction with K in the second year, P had little effect on the number of flowers. Best results were usually obtained at low P fertilization levels.

Table 3. Regression equations[z] for number of flowers and stem length for 'Christian Dior' and 'Happiness' roses.

Equation	Fig. no.	Year	
A	2	1st	$\text{Flowers/plant} = 29.1680 + 0.0307N - 0.0^{5}703N^2 - 0.0^{2}232K + 6.6325V + 0.0^{2}830NV - 0.0^{5}163N^2V$
B	2, 3	2nd	$\text{Flowers/plant} = 13.0580 + 0.0251N - 0.0^{5}530N^2 + 0.0644P + 0.0307K - 0.0^{4}128K^2 - 0.0^{3}208PK + 0.0^{7}850PK^2 + 7.7084V + 0.0^{2}178NV$
C	4	1st	$\text{Avg. stem length} = 10.8605 + 0.0^{2}214N - 0.0^{6}588N^2 - 0.0^{2}235P + 0.0^{2}156K - 0.0^{6}450K^2 - 1.0221V - 0.0^{2}1742PV + 0.6^{4}1940P^2V$
D	4, 5	2nd	$\text{Avg. stem length} = 5.6223 + 0.0^{2}568N - 0.0^{5}187N^2 - 0.0755P + 0.0^{3}433P^2 - 0.0^{4}510K + 0.0^{6}408K^2 + 0.0^{5}465NK - 0.0^{8}149NK^2 + 0.0^{3}212PK - 0.0^{7}813PK^2 - 0.0^{5}121P^2K + 0.0^{9}466P^2K^2 - 1.1421V$

[z]In these equations N, P and K are expressed in lb. per acre, V = +1 for 'Christian Dior' and -1 for 'Happiness'.
The superscripts above the zeros indicate the number of zeros following the decimal point, i. e., $0.0^{3}519 = 0.000519$.

required to maximize first year yields. The fact that these 2 values differ so little indicates the effectiveness of the plastic mulch in stabilizing the nutrient status of the soil.

The number of flowers produced at all levels of N fertilization was slightly less on 'Christian Dior' the second year than in the first year, whereas 'Happiness' yields were practically the same for respective N levels both years. The decrease in yield of 'Christian Dior' the second year was not due to N deficiency because the max yield occurred at a N level below the max rate of application. Subsequent data in this paper do not indicate that P or K were involved in this decrease. Apparently it resulted from some outside influence; probably from an infestation of the two-spotted mite, *Tetranychus urticae* Koch, in January and February, 1966. We believe, for reasons which will not be detailed here, mite injury was more severe on 'Christian Dior' than on 'Happiness'.

Only the effects of various amounts of N on number of flowers has been considered thus far. The effects of N, P, and K can be calculated for a particular year using the equations in Table 3 by letting V = 1 for 'Christian Dior' and V = -1 for 'Happiness', and specifying the N, P, and K fertilizer levels in lb./A.

The first year P had no significant effect on number of flowers (Table 1). The effect of K was to linearly reduce the yield by 0.232 flowers per plant per year for each 100 lb. of K applied. Equation A, Table 3 shows that yield increased up to a max as N fertilization was increased and then decreased with additional N fertilization. This is shown by the curves (Fig. 2). Further, the equation shows that the yield of 'Christian Dior' was greater than that of 'Happiness'. The equation also indicates an N:V interaction in which N increases yield of 'Happiness' less

Average stem lengths (Table 1) of both 'Christian Dior' and 'Happiness' were affected in a parallel quadratic manner by increasing N fertilization (Fig. 4). The optimum level of N for stem length the first year was about 1800 lb./A. In the second year the effect of N on stem length was complicated by significant interactions between N and K and between P and K; but, in general, the average stem length increased quadratically with increasing N to an estimated optimum at 2450 lb./A. This value, as with optimum N levels for yield of flowers the second year, was probably inflated because of depletion of soil N by the second year.

The average increased stem length resulting from increasing N from the min level (300 lb./A) to the optimum level was about

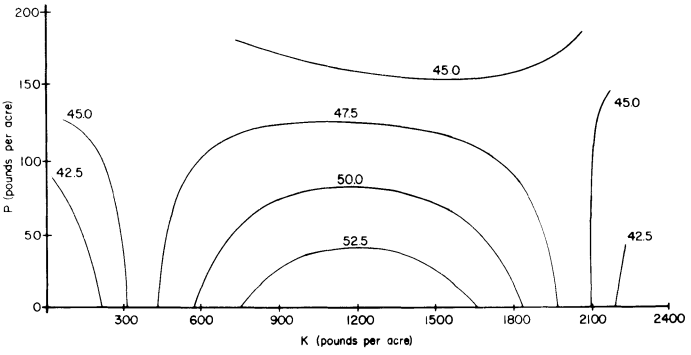

Fig. 3. Number of flowers per plant as affected by P:K interaction in second year. Calculated from equation B in Table 2 with N at 1300 lbs./A.

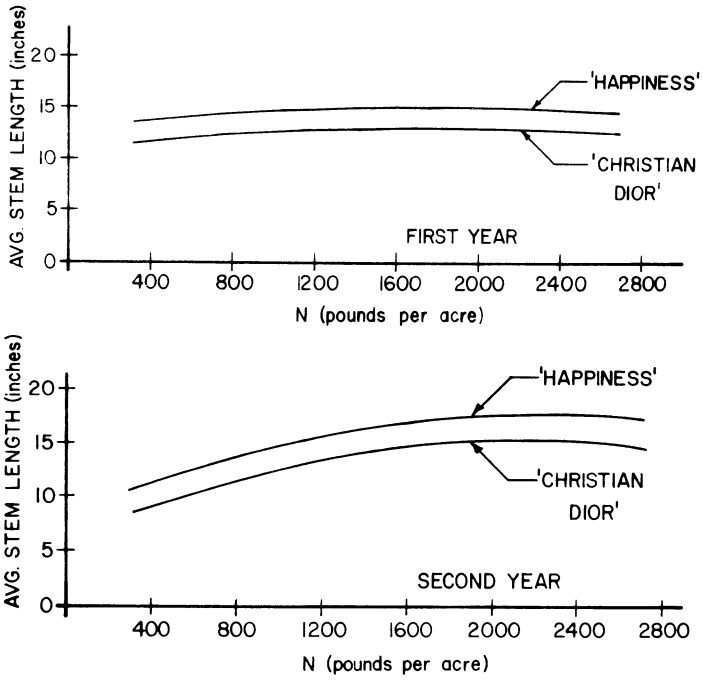

Fig. 4. Stem lengths vs. N fertilization. First year calculated from equation C and second year from equation D in Table 2 with P at 50 lbs./A and K at 750 lbs./A.

1.4 inches for both cultivars the first year. The second year the average increase was about 7 inches, with stems about 2.5 inches longer at the optimum level than in the first year. Regardless of fertilizer levels, 'Happiness' consistently produced longer stems than 'Christian Dior', with the difference uniformly at about 2 inches both years.

The effect of P on stem length the first year was somewhat different for the 2 cultivars. With 'Happiness' average stem length continuously decreased with increasing P. With 'Christian Dior' the rate of decrease became less with increasing P until a rate of about 105 lb./A was reached, and then stem lengths increased with increased P.

K affected stem lengths in a quadratic manner the first year (Table 1), with max lengths at about 1780 lb. K/A for both cultivars. The effects of P and K the second year were complicated by a significant interaction between P and K (Fig. 5). The curves indicate that P had little effect on stem length at lower K levels, but that at levels of K giving max stem lengths, there was also an optimum level for P at about 87 lb./A.

Results from this experiment are in good agreement with those of Waters (9) within the N fertilizer range common to the 2 tests. As N fertilization was increased on 'Tropicana' roses on *R. fortuniana* stock from about 320 to about 960 lb./A per year, the number of flowering stems increased linearly, without evidence that max production was reached at the high rate. Increasing K fertilization (with KNO_3 and K_2SO_4) from about 250 to about 500 lb./A per year had no measurable effect on the growth responses of 'Tropicana' roses. In the present study,

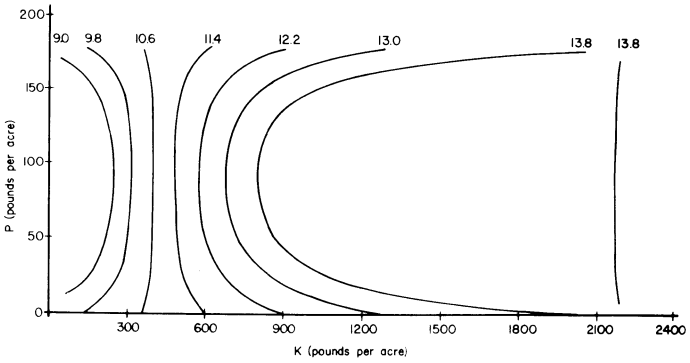

Fig. 5. Stem lengths (inches) as affected by P:K interaction in second year. Calculated from equation D in Table 2 with N at 900 lbs./A.

K fertilization was from 249 to 2241 lb./A, all derived from KCl. The possibility that the decrease in number of flowers with increased K fertilization resulted from excess chlorides is recognized. However, visual evidence of salt damage and of Cl toxicity was particularly looked for when some field ratings were made, and none was observed. The ratings themselves either show no effect of K or a beneficial effect of K fertilization, and naturally the Cl fertilization paralleled the K fertilization. Cl determinations on leaf tissue from the first sampling averaged 0.28 and 0.38% for bushes fertilized at 249 and 2241 lb. K/A, respectively, when both received no P and when N was at 900 lb./A. Both of these Cl values are well under the 1.0% Cl level which has been suggested as being indicative of Cl injury (2). Finally, we showed that stem lengths increased with increasing K (Cl) fertilization, which would suggest no deleterious effect of the Cl. For these reasons, we concluded that Cl toxicity was not a factor in this study.

Literature Cited

1. Bancroft, T. A. 1968. Topics in intermediate statistical methods, Vol. 1, Iowa State Univ. Press, Ames.
2. Bernstein, L. 1964. Salinity and roses. American rose annual. p. 120-124.
3. Horwitz, W. 1970. Official methods of analysis of the association of official analytical chemists. 11th ed. Association of Official Analytical Chemists. Washington, D. C. p. 55.
4. Iley, J. R., and T. W. Young. 1964. Some symptoms of malnutrition in roses. *Proc. Fla. State Hort. Soc.* 77:505-510.
5. Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs, N. J.
6. McFadden, S. E., Jr. 1962. *Rosa fortuniana* compared with other rose rootstocks grown in Florida. *Proc. Fla. State Hort. Soc.* 75:497-500.
7. Snedecor, G. W. 1956. Statistical methods, 5th edition. Iowa State Univ. Press, Ames.
8. Snyder, G. H., T. W. Young, and N. C. Hayslip. 1969. A three year comparison of infrequent heavy fertilization under plastic mulch vs. frequent light applications without mulch for rose production on Immokalee fine sand. *Soil and Crop Sci. Soc. Fla. Proc.* 29:320-331.
9. Waters, W. E. 1967. Influence of nutrition on yield, quality, and chemical composition of 'Tropicana' roses on *Rosa fortuniana* rootstock. *Proc. Fla. State Hort. Soc.* 80:396-400.
10. Young, T. W., J. R. Iley, and N. C. Hayslip. 1966. Response of roses grown with and without plastic mulch at three nitrogen levels. *Proc. Fla. State Hort. Soc.* 79:438-443.