Relation of Temperature and Rainfall to Development of *Xanthomonas* and *Pantoea* Leaf Blights of Onion in Colorado

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ABSTRACT

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During the 1996 to 1999 growing seasons, some areas of Colorado's onion-growing regions experienced a complex of bacterial diseases including leaf blights caused by *Xanthomonas campestris* and *Pantoea ananatis*. Crop losses varied depending on adverse weather (associated with rain, storm, and temperature patterns) and stage of onion plant development. Environmental conditions during vegetative development had no significant association with the initial appearance or subsequent intensity of disease. Both pathogens were active at average high temperatures that ranged from 28 to 35°C during bulbing. Multiple regression models were developed to predict the initial appearance (growing degree day [GDD]) and subsequent *Xanthomonas* leaf blight intensity (final proportion of disease [FPD]) using macroclimatic meteorological conditions, including July average daily high temperature (T_{jmax}), August cumulative rainfall (P_a), and cumulative rainfall in July and August (P_{ja}). Initial disease appearance and disease intensity were described by $GDD_{10} = -6,153.43 + 215.50T_{jmax} - 0.92P_a$ and $FPD = 222.79 - 6.92T_{jmax} + 0.52P_{ja}$, respectively. *Pantoea* leaf blight initial appearance was strongly associated with July average daily temperatures (T_j) and was described by $GDD_{10} = -5,930.43 + 289.07T_j$. Results are discussed in relation to an integrated pest management strategy in Colorado.

Additional keywords: *Allium cepa*, disease forecasting

A bacterial leaf blight caused by *Xanthomonas campestris* (21) first was reported by Alvarez et al. (1) as a problem on onion in Hawaii in 1975. Since then, the disease has been observed in the Caribbean region in 1993 (12), Colorado in 1996 (18), Texas in 1998 (7), South Africa in 1999 (19), and California in 2002 (9). Disease symptoms are varied and include leaves with lenticular water-soaked lesions that elongate into chlorotic streaks, necrosis, tip dieback, and stunting of plants (1,4). A similar disease caused by *X. striiformans* was reported on onion in southern Colorado in 1953 (20), but it differed in 8 of 18 physiological characteristics from the *Xanthomonas* sp. described by Alvarez et al. (1). *X. striiformans* has not been since reported. The pathogen is classified simply as *X. campestris*, pending future research and taxonomic classification (21,24), although Kadota et al. (8) proposed the name *X. campestris* pv. *allii* pv. nov. for a

similar disease of Welsh onion (*Allium fistulosum* L.) reported in Japan.

Very little research has been done on the epidemiology and control practices for *Xanthomonas* leaf blight. Alvarez et al. (1) stated that sprinkler irrigation and dew probably contributed to disease outbreaks, and that contaminated seed could have introduced the pathogen into new production areas in Hawaii. Recent work by Roumagnac et al. (13) confirmed that this bacterium can be transmitted via seed under tropical conditions. Paulraj and O'Garra (12) reported that temperatures of 25 to 30°C and relative humidities of 85 to 95% contributed to the problem in Barbados. They found that sprays of copper- or zinc-based bactericides generally were ineffective, but two onion cultivars from Israel were resistant (10). In addition, proper crop rotation was critical, since isolates of *X. campestris* from onion were pathogenic to legume hosts such as snap bean (*Phaseolus vulgaris* L.), lima bean (*Phaseolus lunatus* L.), soybean (*Glycine max* (L.) Merr.), winged bean (*Psophocarpus tetragonolobus* (L.) DC.), moth bean (*Vigna aconitifolia* (Jacq.) Marechal), and field pea (*Pisum sativum* L.).

Another bacterial leaf blight and bulb decay of onion caused by *Pantoea ananatis* was observed in 1997 by Gitaitis and Gay in Georgia (5) and Schwartz and Otto in

Colorado (16). The disease caused by *P. ananatis* on onion has been referred to as both center rot (22) and *Pantoea* leaf blight and bulb decay (16). Walcott et al. (22) reported that this pathogen can be seed-borne and transmitted by seed. Symptoms include blighted leaves, bleached and rotted seed stalks, and bulb rot (5). Little is known about the epidemiology and control of this disease. Crop rotation strategies are uncertain; similar bacteria (*P. ananas* and *Erwinia ananas*) from other hosts including honeydew melon (*Cucumis melo* L.) (23) and cantaloupe (*Cucumis melo* L. var. *reticulatus* Naudin) have been reported (2), but their relationship to *P. ananatis* pathogenic on onion has not been determined.

A complex of bacterial diseases and their pathogens (15-18), including *X. campestris* and *P. ananatis*, apparently was favored by unusually prolonged periods of rain, high humidity, and dew that accompanied the weather patterns induced by El Niño that flowed into southern Colorado during recent years, especially during 1997. Storm damage, high winds, irrigation water, equipment, and workers presumably all contributed to the dispersal of bacterial pathogens and severity of the diseases which affected onions in various fields and production areas in Colorado. The potential for carryover of these pathogens to the next season and their threat to future crops was considered to be very high under favorable environmental conditions (15). Therefore, during 1996 to 2001 we investigated regional environmental conditions in relation to: (i) epidemics of *Xanthomonas* and *Pantoea* leaf blights and bulb decay of onion, and (ii) forecasts in southern Colorado.

MATERIALS AND METHODS

From 1996 to 2001, field experiments in southern Colorado at the Colorado State University Arkansas Valley Research Center (AVRC) at Rocky Ford (Elev: 1,400 m above sea level, Lat: 38.0333, Long: 103.7000) were conducted from planting in mid-March to harvest in mid-September, each as a randomized complete block design with four replicates. Fertilizer, herbicides, insecticides, and furrow irrigation were applied according to standard grower practices (14). Each plot was 0.9 m wide (1 bed with 2 rows of onions spaced 0.2 m

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apart) $\times$ 7.6 m long, separated by an untreated bed between the neighboring plots. Adapted and commercially acceptable yellow onion cultivars Colorado 6 (1996, 1997) and X 202 (1998 to 2001), highly susceptible to *X. campestris*, and *P. ananatis*, were grown in the trials to screen fungicide and bactericide efficacy (data not reported). Untreated control plots were observed for bacterial disease development during 1996 to 2001 in relation to environmental events.

Environmental summary. From 1996 to 2001, weather data were collected hourly using a CR-10 data logger (Campbell Scientific, Logan, UT) located less than 1 km away from the plots on a grassy site. Daily mean air temperature (Vaisala HMP 35C probe) and cumulative rainfall (TE 525 tipping bucket rain gauge) measurements were obtained or calculated. A growing degree day (GDD) was calculated by $GDD = [(daily\ maximum + daily\ minimum)/2] - 50^{\circ}F$ from emergence, and then converted to GDD₁₀-centigrade by $GDD_{10}\text{-centigrade} = GDD_{50}\text{-Fahrenheit} \times 0.556$.

Weekly observations were made to determine the date of initial appearance of bacterial symptoms. Water-soaked, wilted, chlorotic, and/or necrotic lesions and leaves were considered to be typical symptoms. Representative samples of symptomatic tissue were used for laboratory isolation and confirmation of identity of the pathogen(s) based on characteristic colony development on semi-selective and standard media such as nutrient or yeast dextrose carbonate agar, in addition to Biolog (Biolog, Inc., Hayward, CA) and gas-chromatography fatty acid methyl ester analyses (16,18). In subsequent evaluations made every 7 to 10 days, percentage of canopy area (plant incidence by percent foliar severity) of the entire plot showing disease symptoms was rated.

Regression modeling. Simple and multiple regression models were developed to quantify the effects of environmental conditions upon the initial appearance and subsequent intensity of disease. Macroclimatic meteorological conditions were selected as predictor variables to construct regional forecast models.

Cumulative rainfall and average daily temperatures during biologically significant periods (i.e., vegetative development, bulb initiation) were chosen a priori as predictor variables of initial disease appearance (expressed in growing degree days) and/or final proportion of disease (FPD, expressed as percent disease intensity). Predictor variables included: July and August daily mean high (T_{jmax} , T_{amax}), low (T_{jmin} , T_{amin}), and overall mean temperature (T_j , T_a), respectively, and cumulative rainfall in July (P_j), August (P_a), and 1 July to 30 August (P_{ja}). The final models were selected based upon adjusted R^2 , the number of predictor variables, as well as biological considerations. Because temperature variability is often associated with rainfall events, collinearity diagnostics were performed (SAS PROC REG, SAS Institute, Cary, NC) to assure unique coefficient estimates (11). The influence of each year on the model was quantified using Cook's Distance (D_i), considering years relatively influential if $D_i > 0.50$ and highly influential if $D_i > 1.00$ (11). Years identified as relatively influential were removed and the model refitted before selecting the final predictor variables and parameter estimates to ensure appropriate model fit and prediction.

RESULTS

Environmental summary. Table 1 summarizes the weekly average high temperature, growing degree day (GDD₁₀), and cumulative rainfall recorded at Rocky Ford from week 1 (1 to 7 March) to week 30 (20 to 26 September) during 1996 to 2001. Initial appearance of disease symptoms caused by *X. campestris* and/or *P. ananatis* occurred during weeks 19 to 23, which generally coincided with bulb initiation during weeks 19 to 20 each year, a cumulative rainfall of 74 to 211 cm, and GDD₁₀ of 916 to 1,362 (Table 1). A lower GDD₁₀ value was associated with earlier appearance of these bacterial diseases; i.e., the initial appearance of disease at week 19 in 1996 and 1999 was associated with GDD₁₀ values of 1,004 and 916, respectively.

Average daily high temperatures ranged from 28 to 35°C during the period from

initial disease appearance to maximum disease intensity. Maximum disease intensity (range of 44 to 70% intensity = incidence $\times$ severity) occurred 7 to 8 weeks later as the onion crop approached maturity and harvest, after a cumulative rainfall of 150 to 295 cm and a GDD₁₀ total of 1,525 to 1,870. During 1997 and 1998 when maximum disease reached 70%, there was more than 100 mm of additional rainfall recorded from initial disease appearance to maximum disease intensity; and other years with lower disease values accumulated less than 57 mm of rainfall during this period.

Regression modeling. Early-season conditions before bulb initiation were not significantly associated with the initial appearance (GDD₁₀) or intensity (FPD) of disease. Two models were selected that explain high levels of variability in Xanthomonas leaf blight initial disease appearance and FPD. Disease appearance was strongly associated with T_{jmax} ($P < 0.0001$) and P_a ($P = 0.0017$), and was explained by the plane bounded by $GDD_{10} = -6,153.43 + 215.50T_{jmax} - 0.92P_a$ (Fig. 1). This model described over 99.5% of the observed variability in GDD₁₀ appearance and was highly significant ($P < 0.0001$). The data point from 1999 was relatively influential in this analysis ($D_i = 0.648$). The model was refit without 1999, again producing T_{jmax} and P_a with highly significant parameter estimates (<0.0001 and 0.0023, respectively). The original model including 1999 data was selected as the final forecast model. Collinearity between predictors was not observed.

Temperature during bulb initiation (T_{jmax}) and cumulative precipitation continuing through bulking (P_{ja}) were strongly associated ($P = 0.1389$ and $P = 0.0011$, respectively) with the intensity of Xanthomonas leaf blight, and were described by $FPD = 222.79 - 6.92T_{jmax} + 0.52P_{ja}$ (Fig. 2). T_{jmax} was not significant ($P = 0.139$), but a one-side t test in the direction of the alternative generated a nearly significant ($P = 0.069$) parameter estimate. T_{jmax} was maintained in the model because near significance, despite a small sample size ($n = 7$, df error = 4), was suggestive of a meas-

Table 1. Onion Xanthomonas leaf blight development at Rocky Ford during 1996 to 2001

Year	Initial disease appearance			Maximum disease intensity			
	Week ^v	Rain ^w	GDD ₁₀ ^x	Week	Rain ^y	GDD ₁₀	% Disease ^z
1996	19	154.4	1,004	26	211.8	1,605	44
1997	22	152.2	1,227	28	295.2	1,710	70
1998	20	74.4	1,051	26	181.3	1,525	70
1999	19	194.6	916	27	225.1	1,720	58
2000	21	119.9	1,191	26	150.4	1,634	26
2001	23	211.6	1,362	30	228.4	1,870	<1

^v Bulb initiation occurred during weeks 19 to 20 each year.

^w Cumulative rain (mm) from week 1 to week of initial disease appearance.

^x GDD₁₀ = growing degree day centigrade, base = 10. A growing degree day was calculated by $GDD = [(daily\ maximum + daily\ minimum)/2] - 50^{\circ}F$ from emergence, and then converted to GDD₁₀-centigrade by $GDD_{10}\text{-centigrade} = GDD_{50}\text{-Fahrenheit} \times 0.556$.

^y Total rain (mm) from week 1 to week of maximum disease intensity.

^z Disease intensity determined by plant incidence $\times$ foliar percent severity of the entire plot.

Fig. 1. Plane describing initial appearance of *Xanthomonas* leaf blight in southern Colorado, bounded by July mean daily high temperature (T_{jmax}) and August cumulative rainfall (P_a) as described by $GDD_{10} = -6,153.43 + 215.50T_{jmax} - 0.92P_a$.

Fig. 2. Plane describing *Xanthomonas* leaf blight maximum intensity in southern Colorado, bounded by July mean daily high temperature (T_{jmax}) and August cumulative rainfall (P_j) as described by $FPD = 222.80 - 6.92T_{jmax} + 0.52P_{ja}$.

urable effect of temperature on disease intensity. Influence diagnostics indicated that 2001 was highly influential ($D_i = 1.54$) in the full model. The unique environmental conditions associated with the 2001 season ($P_{ja} < 51.1$, $T_{jmax} = 34.92$), although influential, were important epidemiologically to disease intensity ($FPD < 1\%$) and improved prediction over a broader range of temperature and rainfall patterns. Collinearity between predictors was not observed. GDD_{10} and FPD model parameters are summarized in Table 2.

Pantoea leaf blight and associated bulb decay were observed in each year from 1997 to 2000, but macroclimatic temperature and rainfall events were only marginally associated with the initial appearance or intensity of disease. Rainfall and temperature during late vegetative and early reproductive development (expressed as T_j and P_j) were significantly and nearly significantly (one-sided $P = 0.029$ and $P = 0.092$, respectively) associated with the initial appearance of disease symptoms. The appearance of *Pantoea* leaf blight was described by $GDD_{10} = -5,930.43 + 289.07T_j$, and explained 88.7% of the variability in initial disease appearance during outbreak years. According to this model, initial appearance of *Pantoea* leaf blight symptoms is expected to be delayed 28.9 GDD_{10} for every 0.10 increase in July daily mean temperatures after 1,007 accumulated GDD_{10} . The small sample population ($n = 4$, $df_{error} = 2$) used in this analysis limits the usefulness of this relationship for disease forecasting, however.

DISCUSSION

X. campestris and *P. ananatis* are endemic in southern Colorado onion growing regions, as evidenced by their consistent outbreaks in recent years. Moisture and temperature conditions generally favored infection during onion bulbing each year as plants made the transition from vegetative to reproductive development. The intensity of *Xanthomonas* leaf blight, however, varied in relation to temperature and rainfall at bulb initiation and continuing into bulb development as described by the derived FPD model (Fig. 2). Both pathogens were active during the average high tempera-

Table 2. Parameter estimates, significance, and collinearity of predictor variables and *Xanthomonas* leaf blight growing degree day (GDD) and final proportion of disease (FPD) forecast models

Predictor variable	Parameter estimate	$P > t $	Variance inflation	Condition index ^z	Model $\sqrt{\text{MSE}}$	Model R^2	Model adj. R^2	Model F value	Model $P > F$
GDD model									
Intercept	−6,153.43	<0.0001	0	NA	13.33	0.995	0.993	411.81	<0.0001
$T_{j\max}$	215.50	<0.0001	1.066	1.00					
P_a	−0.92	0.0017	1.066	1.29					
FPD model									
Intercept	222.80	0.16	0	NA	6.84	0.951	0.926	38.74	0.0024
$T_{j\max}$	−6.92	0.14	1.012	1.00					
P_{ja}	0.52	0.0011	1.012	0.90					

^z NA: No condition index generated. Collinearity diagnostics adjusted for intercept.

tures that ranged from 28 to 35°C in southern Colorado during the infection period. This is at least 5°C higher than that reported to favor *Xanthomonas* outbreaks in Barbados (12). The intensity of leaf blight caused by *Xanthomonas* was reduced with increasing temperature (Fig. 2). The initial appearance of *Xanthomonas* leaf blight was accurately predicted using T_{jmax} and P_a , explaining 99.5% of the observed variability in *X. campestris* appearance. This model could be used by growers on a regional basis to improve timing of the first application of a copper-based bactericide and eliminate unnecessary early-season sprays. Growers currently rely upon crop phenology to time bactericide applications (15). The models developed also utilize macroclimatic meteorological conditions, freeing growers from the burden and expense of extensive microclimatic monitoring (6). Both the GDD₁₀ and FPD models assume that low levels of initial inoculum are present and that the host is highly susceptible. The lack of resistance within commercially accepted Spanish-type onions (H. F. Schwartz, unpublished) and consistent *Xanthomonas* and *Pantoea* leaf blight epidemics in recent years suggest that these assumptions will usually be satisfied in southern Colorado.

Subsequent sprays may be timed according to the FPD model after further study and extensive validation in southern Colorado and possibly other onion producing regions. High daily mean temperatures and low cumulative rainfall as described by the FPD model would suggest longer spray intervals and/or reduced rates, whereas rainfall accompanied by more moderate temperatures would suggest short intervals between applications with possibly higher rates.

The lack of *Pantoea* leaf blight development in 1996 with apparently favorable environmental conditions suggests that other unmeasured variables may be epidemiologically important to disease appearance and subsequent development. Although T_j was lowest in 1996 (23.92) and P_j (61.98) the second highest recorded over the duration of this study, disease was not observed in experimental plots or commercial fields. It is plausible that *P. ananatis* was not introduced into Colorado until 1997, possibly via infested seed (22). Because *P. ananatis* and its disease on onion were not reported until 1997 (5), the disease may have been present in commercial fields in southern Colorado in 1996 at a low incidence. Alternatively, the pathogen and its disease may have been confused with or misdiagnosed as *Erwinia carotovora* subsp. *carotovora* and bacterial soft rot and/or saprophytic *P. agglomerans*

(15). In 2001, however, high mean daily temperatures during late vegetative growth and bulb initiation ($T_j = 25.77$), combined with relatively dry conditions in late July (Table 1), appear to have suppressed pathogen and disease development. More research on the epidemiology of this disease is warranted to understand the environmental conditions that favor and suppress it, in order to develop effective multi-tactic management strategies.

A preventive spray strategy on a 5- to 7-day (moderate to high pressure) or 7- to 10-day (low to moderate pressure) schedule with a copper-based bactericide (e.g., Champ, Kocide, NuCop) mixed with an ethylenebisdithiocarbamate fungicide (e.g., Maneb, Manex, Penncozeb, Mancozeb, Dithane) has provided an effective and economical tool to protect onion plants from serious infection by these types of bacterial pathogens, especially *X. campestris*, during late vegetative to mature bulb plant stages (15). Unpublished data from 1996 to 1999 revealed that an estimated investment for 10 weekly sprays of a copper-based program at \$6 per hectare per spray is \$60 per hectare with a conservative yield increase of 10%. This would yield an additional 390 kg or \$120 per hectare, which is a 2 to 1 return for the Colorado onion industry based on 1996 to 2001 production averages of 16 Mt/ha at \$0.31 per kg market price (3).

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LITERATURE CITED

- Alvarez, A. M., Buddenhagen, I. W., Buddenhagen, E. S., and Domen, H. Y. 1978. Bacterial blight of onion, a new disease caused by *Xanthomonas* sp. *Phytopathology* 68:1132-1136.
- Bruton, B. D., Wells, J. M., Lester, G. E., and Patterson, C. L. 1991. Pathogenicity and characterization of *Erwinia ananas* causing a postharvest disease of cantaloupe fruit. *Plant Dis.* 75:180-183.
- Colorado Agricultural Statistics. 2001. Annual Report, Colorado Department of Agriculture, Denver.
- Gitaitis, R. D., Davis, R. M., and Mohan, S. K. 1995. Diseases caused by bacteria and a yeast. Pages 30-33 in: *Compendium of Onion and Garlic Diseases*. H. F. Schwartz and S. K. Mohan, eds. American Phytopathological Society, St. Paul, MN.
- Gitaitis, R. D., and Gay, J. D. 1997. First report of a leaf blight, seed stalk rot, and bulb decay of onion by *Pantoea ananas* in Georgia. *Plant Dis.* 81:1096.
- Gleason, M. L., Taylor, S. E., Loughin, T. M., and Koehler, K. J. 1994. Development and validation of an empirical model to estimate

the duration of dew periods. *Plant Dis.* 78:1011-1016.

- Isakeit, T., Miller, M. E., Barnes, L. W., Dickstein, E. R., and Jones, J. B. 2000. First report of leaf blight of onion caused by *Xanthomonas campestris* in the continental United States. *Plant Dis.* 84:201.
- Kadota, I., Uehara, K., Shinohara, H., and Nishiyama, K. 2000. Bacterial blight of Welsh onion: A new disease caused by *Xanthomonas campestris* pv. *alli* pv. *nov.* *J. Gen. Plant Pathol.* 66:310-315.
- Nunez, J. J., Gilbertson, R. L., Meng, X., and Davis, R. M. 2002. First report of *Xanthomonas* leaf blight of onion in California. *Plant Dis.* 86:330.
- O'Garro, L. W., and Paulraj, L. P. 1997. Onion leaf blight caused by *Xanthomonas campestris*: Alternative hosts and resistant onion genotypes. *Plant Dis.* 81:978-982.
- Ott, R. L., and Longnecker, M. T. 2001. *An Introduction to Statistical Methods and Data Analysis*. 5th ed. Duxbury Press, Pacific Grove, CA.
- Paulraj, L., and O'Garro, L. W. 1993. Leaf blight of onions in Barbados caused by *Xanthomonas campestris*. *Plant Dis.* 77:198-201.
- Roumagnac, P., Gagnevin, L., and Pruvost, O. 2000. Detection of *Xanthomonas* sp., the causal agent of onion bacterial blight, in onion seeds using a newly developed semi-selective isolation medium. *Eur. J. Plant Pathol.* 106:867-877.
- Schwartz, H. F., and Bartolo, M. E. 1995. Onion IPM and Production Bulletin 547A. Colorado State Univ. Agric. Exp. Stn. Ext. Bull., Fort Collins.
- Schwartz, H. F., and Otto, K. J. 1998. Onion bacterial disease management in Colorado. Pages 214-218 in: *Proc. 1998 National Onion (and other Allium) Res. Conf.*, Sacramento, CA.
- Schwartz, H. F., and Otto, K. 2000. First report of a leaf blight and bulb decay of onion by *Pantoea ananatis* in Colorado. *Plant Dis.* 84:808.
- Schwartz, H. F., and Otto, K. 2000. First report of a bulb decay of onion by *Enterobacter cloacae* in Colorado. *Plant Dis.* 84:808.
- Schwartz, H. F., and Otto, K. 2000. First report of a leaf blight of onion caused by *Xanthomonas campestris* in Colorado. *Plant Dis.* 84:922.
- Serfontein, J. J. 2001. *Xanthomonas* blight of onion in South Africa. *Plant Dis.* 85:442.
- Thomas, W. D., Jr., and Weinhold, A. R. *Xanthomonas striaformans*, a new bacterial pathogen of onion. *J. Colo.-Wyo. Acad. Sci.* 4(5):22.
- Vauterin, L., Rademaker, J., and Swings, J. 2000. Synopsis on the taxonomy of the genus *Xanthomonas*. *Phytopathology* 90:677-682.
- Walcott, R. R., Gitaitis, R. D., Castro, A. C., Sanders, F. H., Jr., and Diaz-Perez, J. C. 2002. Natural infestation of onion seed by *Pantoea ananatis*, causal agent of center rot. *Plant Dis.* 86:106-111.
- Wells, J. M., Sheng, W.-S., Ceponis, M. J., and Chen, T. A. 1987. Isolation and characterization of strains of *Erwinia ananas* from honeydew melons. *Phytopathology* 77:511-514.
- Young, J. M., Bull, C. T., De Boer, S. H., Firrao, G., Gardan, L., Saddler, G. E., Stead, D. E., and Takikawa, Y. 2001. Classification, nomenclature, and plant pathogenic bacteria—a clarification. *Phytopathology* 91:617-620.