Queensland Journal of Agricultural and Animal Sciences Vol. 43 (2), 83-89 (1986)
Published by the Queensland Department of Primary Industries

Climatic influences on mango production in the Bowen district

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Summary

The relationship between annual mango production in the Bowen district during the years 1962–75 and 13 possible determinant factors including climatic influences was investigated. Annual mango production was significantly correlated with previous annual production ($P<0.10$), previous previous annual production ($P<0.05$), number of bearing trees ($P<0.05$), summer rain ($P<0.01$), annual rain ($P<0.05$), and incidence of cold days in the pre-flowering period ($P<0.05$). These suggested determinant factors are discussed in relation to their possible mode of action and their possible use in regulating annual production. Ninety-four per cent of the variation in production was explained by the equation:

$$Y=447\ 460-0.463X_1+21.15X_3+609X_4+1089X_9$$

Where X_1 is previous annual production, X_3 is number of bearing trees, X_4 is summer rain and X_9 is June to August rain. The value of this equation as a model for prediction of annual mango production has not been tested, but it provides a useful basis for planning of additional research.

INTRODUCTION

A substantial and cyclic variation in total mango production in successive years is apparent from the statistical records of mango production in the Bowen district.Total Bowen production ranges from 484 to 1619 tonnes for the period 1962–75. This variation is not conducive to stable markets or industry expansion. Also, the cycle is not precise and successive low-production years or high-production years occur. A knowledge of the major factors associated with this irregular production would be useful in understanding the basic causes and ultimately determining means of stabilising production. Hence, the relationship between district production and possible climatic influences was investigated.

The problem of irregular, biennial or alternate bearing is well known in mango and has been described by many workers including Gangolly *et al.* (1957), Singh (1968) and Prasad and Patek (1970) in India, Meulen (1971) in South Africa, Valmayor (1968) in the Philippines, and Ruehle and Ledin (1955) in Florida. However, the problem of alternate bearing in mango in the dry tropics of Queensland has not previously been documented.

Most workers agree that the alternate bearing cycle in mango need not be strictly biennial and that alternate bearing involves vegetative growth and fruiting being at the expense of each other. Heavy flowering in on-years results from heavy and early shoot development in off-years. However, alternate bearing is not explained as simply as this. Singh (1968) stated that nutrient conditions, emergence and development of vegetative growth flushes, their biochemical status and intensity of flowering and fruiting are all interrelated in their influence on the generation of an alternate bearing rhythm. Also, fruitfulness in mango is determined by variety, age of tree, intensity of blossoming and climatic factors during flowering and fruit development stages (Prasad and Patek 1970). A knowledge of the relative importance of these factors in mango production in the Bowen district will be useful in understanding the causes of alternate bearing and suggesting relevant control measures.

Possible control measures for alternate bearing discussed by Ruehle and Ledin (1955), Valmayor (1968), Singh (1968), Prasad and Patek (1970) and Meulen (1971) included cultural practices such as irrigation, fertiliser application, pest control and pruning, as well as flower induction, flower and fruit thinning and scion and rootstock selection. All measures aim to reduce excessive crop in the on-year or increase flowering or set in the off-year.

The mango industry in Queensland is mainly located in the dry tropics (defined by 19° and 21°S latitude) and is essentially dependent on one variety, Kensington Pride. The normal annual cycle of growth of cv. Kensington at Bowen together with average monthly minimum and maximum temperatures and monthly rainfall is illustrated in Figure 1. Flowering and fruit development normally occur during June to August and August to December, respectively, in this variety in the Bowen district. Vegetative growth is at its strongest during the December to March period after crop harvest and with the onset of summer rains, and it is from this growth that flowers are ultimately produced for the next crop. A dormant phase when growth is minimal normally occurs during May to July, the immediate pre-flowering period.

The mango grows readily in a wide climatic range and the limits of rainfall and temperature needed for adequate commercial production seem well defined. The distribution of rainfall is more important than total rainfall for ideal growth and fruiting. Hobson (1969) considered that at least 600 mm of summer rainfall were required for mango, although irrigation can be used for supplementation in areas of low rainfall. A growth check as a result of drought, or other means prior to bloom emergence is necessary to stimulate intense and uniform flowering (Naik 1949; Meulen 1971). Also, a dry period during flowering and fruit development is essential since cropping is reduced substantially by rains, dews or fogs at flowering (Singh 1968), during early fruit development (Stephens 1960), and at fruit ripening (Gangolly *et al.* 1957). Rainfall records from the coastal and subcoastal dry tropics of Queensland indicate that 750 mm of rainfall are normally received in the summer (December to March) period, whereas the pre-flowering (May to July) period and the period of flowering and fruit development (June to November) together normally receive less than 200 mm. Hence, total rainfall, rainfall from December to March, from May to July, from June to August and from August to November in the Bowen district were considered in the present study as possible major climatic determinants of mango production.

The coastal and subcoastal dry tropics region of Queensland is generally frost-free and mean monthly minimum and mean monthly maximum temperatures range from 14° to 24°C and 24° to 31°C respectively. Singh (1968) considered the optimum growth temperature for mango as being 24° to 27°C. Also, the limit of minimum temperatures (2° to 3°C) is regarded as more critical than the limit of maximum temperatures (40° to 44°C) as high humidities can partially offset the effect of high temperatures. Campbell and Malo (1967) state that death of flowers and small fruit in mango in Florida occurred when air temperatures dropped to less than 5°C for a few hours. High spring and summer temperatures hasten development of fruit and bring it to maturity before the onset of the wet season.In contrast, hot dry winds of high velocity have been observed by the senior author and reported by Singh (1968) to cause losses of young fruit and leaf. Hence, the following factors were also selected for study: incidence of days with low temperatures (less than 10°C) during the pre-flowering period, during the flowering and early fruit development period; incidence of days with high temperatures (more than 30°C) during fruit development and maturation; and incidence of days with high velocity winds (more than 21 knots) during fruit development.

MATERIALS AND METHODS

The normal annual cycle of growth of cv. Kensington at Bowen (Figure 1) was considered together with climatic elements and critical rainfall and temperature requirements in selecting factors as possible influences on annual mango production.

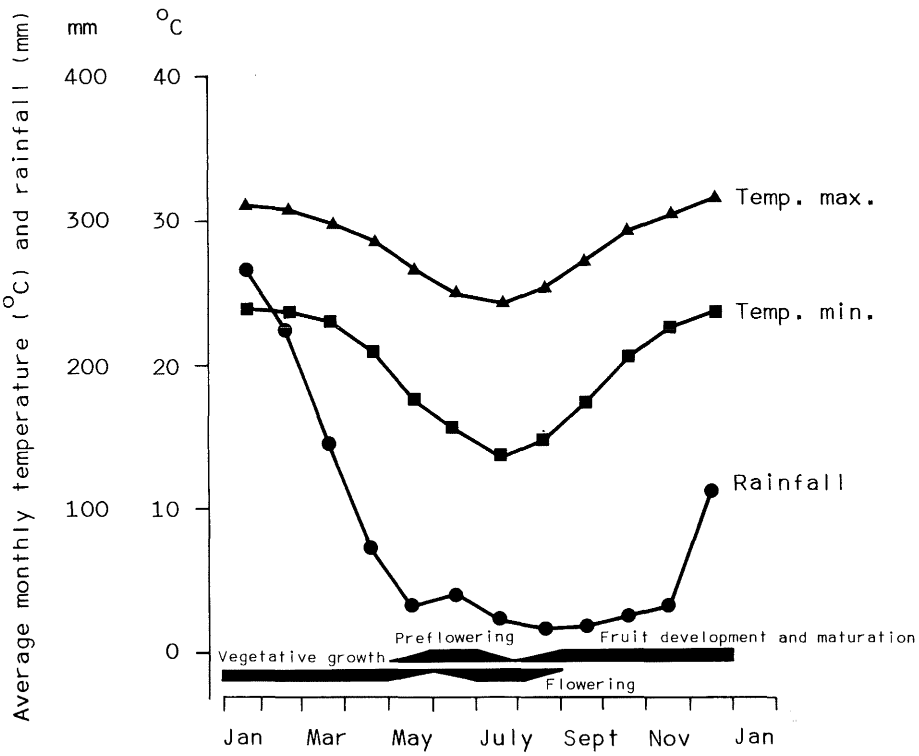

Figure 1. Annual cycle of climate and growth in mango cv. Kensington at Bowen.

The 13 factors selected as possible influences on annual production (Y) are given in Table 1.

Data on production and climate from 1962–75 are listed in Table 2. These data were subjected to multiple linear regression analysis using the all possible regressions technique.

Table 1. Selected factors in Bowen mango production

	Variables	Source
X_1	Previous annual production (kg)	a
X_2	Previous previous annual production (kg)	a
X_3	No. bearing trees	b
X_4	Rain December to March (mm)	c
X_5	Rain annual (mm)	c
X_6	Rain previous annual (mm)	c
X_7	Rain May to July (mm)	c
X_8	No. days May to July temps <10°C	c
X_9	Rain June to August (mm)	c
X_{10}	No. days June to September temps. <10°C	c
X_{11}	Rain August to November (mm)	c
X_{12}	No. days August to December temps >30°C	c
X_{13}	No. Days August to November winds >21 knots	c
Y	Annual production (kg)	a

*a=Bowen Farmers Co-operative Association Ltd–fruit loadings.

b=Australian Bureau of Statistics, Queensland office.

c=Bureau of Meteorology, Bowen Recording Station.

Table 2. Bowen mango production and possible determinant factors, 1962 to 1975

Year	Annual production (kg)	Previous annual production (kg)	Previous annual production (kg)	No. bearing trees	Rain Dec–Mar (mm)	Rain annual (mm)	Rain previous annual (mm)	Rain May–Jul (mm)	No. days temp. <10°C May–Jul	Rain Jun–Aug (mm)	No. days temp. <10°C Jun–Sep	Rain Aug–Nov (mm)	No. days temp. >30°C >21 k. Aug–Dec	No. days wind Aug–Nov
1962	668 316	858 531	714 092	10 816	561	678	429	53	3	9	3	6	76	4
1963	908 966	668 316	858 531	11 293	613	796	678	21	17	75	8	70	31	3
1964	530 823	908 966	668 316	10 764	324	641	796	92	2	84	17	93	62	1
1965	706 189	530 823	908 966	12 814	349	534	641	43	4	15	3	14	40	3
1966	695 444	706 189	530 823	12 460	590	640	534	29	3	57	12	118	43	3
1967	1 045 240	659 444	706 189	11 374	520	925	640	329	4	307	6	24	37	0
1968	940 275	1 045 240	659 444	11 764	981	1 201	925	171	7	39	4	35	53	0
1969	647 959	940 275	1 045 240	12 697	224	410	1 201	59	2	35	9	89	56	0
1970	1 195 130	647 959	940 275	16 564	981	1 198	410	8	0	48	2	171	37	3
1971	922 563	1 195 130	647 959	18 192	729	1 166	1 198	94	6	161	11	131	80	2
1972	1 295 780	922 563	1 195 130	18 834	1 315	1 163	1 166	39	2	14	5	34	54	0
1973	483 762	1 295 780	922 563	13 773	729	1 132	1 163	23	0	31	2	186	35	0
1974	1 619 280	483 762	1 295 780	14 993	1 678	1 646	1 132	77	27	20	29	120	53	0
1975	592 960	1 619 280	483 762	11 629	736	1 560	1 646	51	6	117	6	276	54	2

RESULTS AND DISCUSSION

The correlation matrix for annual Bowen mango production (kg) and determinant factors for the period 1962–75 is recorded in Table 3. Annual production was positively correlated ($P<0.05$) with previous previous annual production and negatively correlated ($P<0.10$) with previous annual production. This supports observations that an alternate bearing pattern was well established in the Bowen district as in India (Singh 1968) and South Africa (Meulen 1971) and that district production in any one year was influenced by the production of the previous two years.

Table 3. Correlation matrix, annual production (kg)

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	Y
X_1	1.00													
X_2	−0.45	1.00												
X_3	0.01	0.49	1.00											
X_4	−0.11	0.54	0.57	1.00										
X_5	0.33	0.16	0.41	0.81	1.00									
X_6	0.72	0.10	0.25	0.25	0.52	1.00								
X_7	−0.06	−0.22	−0.26	−0.08	0.05	−0.06	1.00							
X_8	−0.35	0.38	−0.02	0.55	0.44	0.16	0.02	1.00						
X_9	0.12	−0.45	−0.13	−0.24	0.08	0.02	0.78	−0.06	1.00					
X_{10}	−0.30	0.27	0.05	0.37	0.24	0.20	0.04	0.71	−0.01	1.00				
X_{11}	0.59	−0.21	0.15	0.14	0.54	0.54	−0.36	−0.01	0.04	0.10	1.00			
X_{12}	0.33	−0.18	0.17	0.00	0.02	0.25	0.01	−0.05	−0.06	0.22	0.09	1.00		
X_{13}	−0.19	−0.41	−0.19	−0.31	−0.30	−0.54	−0.45	−0.10	−0.16	−0.26	−0.00	0.07	1.00	
Y	−0.50	0.62	0.56	0.83	0.55	−0.03	0.16	0.58	0.01	0.41	−0.17	−0.07	−0.26	1.00

Correlation coefficient values

$r(12, 10\%)=0.4575$

$r(12, 5\%)=0.5324$

$r(12, 1\%)=0.6614$

Annual production was correlated ($P<0.05$) with the number of bearing trees which is obvious and expected. Annual production was also correlated ($P<0.01$, $P<0.05$, $P<0.05$, respectively) with summer rain, annual rain, and number of cold days in the May to July (pre-flowering) period. These factors were probably the major climatic determinants of annual mango production in the Bowen district as significant correlations were not obtained for the other seven factors.

Two of the major climatic factors affecting mango production in the Bowen district were annual rainfall, and in particular, summer rainfall, which is to be expected, as December to March rainfall is normally 70 to 75% of annual (January to December) rainfall. A departure from normal annual rainfall or from normal summer rainfall adversely affects district production. Irrigation of mango orchards is not a common practice in the Bowen district, which is the most likely reason for the current importance of rainfall as a determinant of production.

Annual rainfall obviously contributes to general needs of mango for growth and fruit development over the year. Good early summer rains, as the previous year's crop matures, in the absence of irrigation provides the major stimulus for extensive early vegetative growth through to the dormant phase early in the May to July period. Maturation of these vegetative growth flushes during the dormant phase also (presumably) encourages uniform bloom emergence and strong flowering, the pre-requisite for good fruiting as is stated by Naik (1949) and Meulen (1971). In these terms, light or late summer rains may adversely affect subsequent flowering and fruit production. Hence, timely irrigation together with fertiliser application in early summer may be a practical strategy for stimulating subsequent production. Also, such early summer irrigation at the beginning of anticipated off-years may be a means of regulating alternate bearing. Irrigation trials along the lines mentioned may be useful to test these suggestions.

The incidence of cold days in the May to July pre-flowering period was significantly correlated with annual production in this study whereas the incidence of rainfall in the same period did not have a significant correlation. The dormant phase in mango in the Bowen district occurs early in the May to July period, with flowering occurring in the June to August period. Flowering and fruitfulness in mango is considered by Naik (1949) and Meulen (1971) to be favoured by a dormant phase or growth check in the immediate period prior to normal bloom emergence. Hence, the occurrence of cold rather than drought may be the major factor involved in checking growth and hence favouring flowering and production in mango in the Bowen district. Also, Meulen's (1971) recommendation that irrigation or fertiliser applications be withheld in the May to July period until flowering is assured seems worth supporting.

Research on alternate bearing in mango in India by Singh (1968), and in the Philippines by Valmayor (1968), stresses the importance of the inverse relationship between fruiting on one hand, and good early vegetative growth as a prerequisite to acceptable flowering on the other hand. A knowledge of the relative intensity of vegetative growth, flowering and fruiting of shoots from different trees and even limbs on the one tree over several years in Bowen orchards may be useful in further understanding the importance of the incidence of flowering in alternate bearing.

Low correlations were obtained for annual production and seven of the 13 factors.The detrimental effect on cropping of the occurrence of rains and dews during flowering and fruiting has been well reported (Gangolly *et al.* 1957; Stephens 1960; Singh 1968) as has the occurrence of cold during flowering and fruit development and the occurrence of high temperatures and high winds during fruit development (Singh 1968). The lack of significant correlations between annual production and factors involving rainfall, wind and high and low temperatures during flowering and fruit development, was unexpected. However, mango production may not have been severely limited by the occurrence of these climatic factors in the 1962–75 period which would only confirm that the dry tropics is generally suitable for mango production. The pre-1962 data on factors involved in this study were not considered dependable and were omitted. Additional years and possibly further factors need to be considered in further studies of this type.

Potential prediction equations contained the following variables:

(1) Y, X_1, X_4, X_9 (R^2=0.92)

(2) Y, X_1, X_3, X_4, X_9 (R^2=0.94)

(3) Y, X_1, X_2, X_4, X_9 (R^2=0.94)

(4) Y, X_1, X_3, X_4, X_7 (R^2=0.93)

(5) Y, X_1, X_4, X_6, X_9 (R^2=0.93)

The variable sets (2) and (4) were preferred since they contain X_3, the number of bearing trees, a factor of obvious relevance. Variables X_9 and X_7 are highly correlated (as expected since the rain measurement periods overlap). Variable set (2) was selected on the basis of its higher R^2 value.

The preferred four variable prediction equation obtained included previous annual production (X_1), number of bearing trees (X_3), summer rain (X_4), and June to August rain (X_9), and accounted for 93.9% of the variation. The prediction equation is:

$$Y=447\ 460-0.463X_1+21.15X_3+609X_4+1\ 089X_9$$

The partial regression co-efficients of X_1, X_4 and X_9 are significant ($P<0.01$, $P<0.01$, $P<0.05$, respectively). However, the value of this equation in prediction remains to be tested.

The regression co-efficients for the independent variables in the preferred equation were of expected sign except for X_9 (June to August rain) which was positive. The stimulation of production by rain during the flowering period June to August is contrary to reports by Singh (1968) and Stephens (1960) who mention the deleterious effect on cropping of rains, dews or fogs at flowering and during early fruit development. However, the type of rain may be critical. Storm rains of short duration may not be as damaging as extended periods of drizzling rain. On this basis, the number of wet days recorded during flowering and fruiting may be a determinant of Bowen mango production and would be worthwhile including in any future investigation of this type. A likely explanation for June to August rainfall stimulating production is that some rainfall during flowering has a beneficial effect on final production because of fulfilment of fruit development needs. Fruits continue to develop and mature in the Bowen district over August to November during which period little rainfall is received. Thus, irrigation treatments during fruit development should favour higher production. This suggestion is supported by Meulen's (1971) observation that heavy flood irrigation or underhead sprinkler irrigation together with fertiliser application is most beneficial on mature trees from the time bloom emergence is assured. The value of such an irrigation treatment seems worth investigating.

The climatic factors involving annual and summer rainfall and temperature in the pre-flowering phase which were discussed previously, seem most likely to be responsible for the maintenance and sychronisation of alternate bearing in mango in the Bowen district. A strategy of irrigation and fertiliser use after crop maturation to encourage early vegetative growth and when flowering is assured to encourage fruit set and development seem most worth assessment as possible means of controlling alternate bearing.

No comprehensive remedy for alternate bearing is likely until the basic causes are better understood. However, other cultural, chemical and genetic measures described by Prasad and Patek (1970) may be useful in modifying the alternate bearing cycle, through their influence on both vegetative and reproductive growth.The contribution these factors may make to regulating annual production in the Bowen situation also needs to be considered.

References

Campbell, C. W. and Malo, S. E. (1967), *The Mango,* Fruit Crops Fact Sheet 2. Agricultural Extension Service, University of Florida.

Gangolly, S. R., Singh, R., Katyal, S. L. and Singh, D. (1957), *The Mango,* Indian Council of Agricultural Research, New Delhi.

Hobson, L. (1969), Mango Production in South Africa, *The South African Citrus Journal,* Part 1, Jan 1969, 15–17. Part 2, Mar 1969, 12–16.

Meulen, A. (1971), *Mango Growing in South Africa,* Leaflet 48, Sub-Tropical Fruit Series 7, Mango Series 1, Citrus and Sub-Tropical Fruit Research Institute, Nelspruit.

Naik, K. C. (1949), *South Indian Fruits and Their Culture,* Varadachary and Co., Madras.

Prasad, A. and Patek, A. P. (1970), Biennial Bearing in Mango, *Tropical Agriculture* **26** (1), 35–56.

Ruehle, G. D. and Ledin, R. B. (1955), *Mango Growing in Florida,* University of Florida, Agricultural Experiment Station's Bulletin No. 574.

Singh, L. B. (1968), *The Mango,* second edition Leonard Hill, London.

Stephens, S. E. (1960), Mango Growing in Queensland, *Queensland Agricultural Journal* **86** (12), 761–66.

Valmayor, R.V. (1968), *The Mango—Its Botany and Production.* University of Philippines, College of Agriculture, Laguna.

(Accepted for publication 8 May 1986)

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