Indian J. Hort. 69(3), September 2012: 399-403

Requirement of major nutrients for annatto (*Bixa orellana* L.) seed yield and bixin content

Sudhir Kumar*, R. Venugopalan, V.K. Rao**, A.K. Nair** and R. Chithiraichelvan*****
Central Horticulture Experiment Station (IIHR), Chettalli, Kodagu 571 248, Karnatakai

ABSTRACT

A field experiment was conducted during 2002-07 at CHES, Chettalli, Karnataka to study the optimum requirement of major nutrients for the optimum seed yield and bixin content in annatto plant. Application of 140 g N + 60 g P_2O_5 + 150 g K_2O/pl/year recorded higher seed yield (2.674 kg/plant) and bixin content than other treatments. Response Surface Model analysis revealed that the optimum dose of N and K_2O (with fixed P_2O_5) for optimum seed yield (2.99 kg/plant) would be 103.15 and 134.94 g/plant, respectively and the optimum dose of the nutrients would be 102.81 g/plant of N and 134.06 g/plant of K_2O for the optimum (2.6%) bixin content.

Key words: Annatto, seed yield, bixin content, Response Surface Model.

INTRODUCTION

Annatto is known for natural dye, which is mainly used in consumable products and cosmetics. Some work has been carried out in India and abroad but still research is to be carried out on different aspects of cultivation of this crop.

Recently, there is considerable interest in designs for fitting response surfaces and determining optimum operating conditions in various fields. Response surface design and their analysis are used to find combinations of a number of experimental factors that will lead to optimum responses. Second order experimental design having equal predictability in all directions at a constant distance from the centre of the design is called second order rotatable design. The main usefulness of the design is that they have relatively small number of experimental points, which allows the fitting of the second order response surfaces (Maximo and Singh, 3). In the present study this is employed for finding the optimum combination of N, P_2O_5 and K_2O for maximizing the seed yield and bixin content in annatto. Such type of study has also been conducted by Sharma *et al*. (7), Ramachander *et al*. (5), and Reddy *et al*. (6) for perennial crops like mandarin, grape, sweet orange and mango. Therefore, in present study a nutritional trial has been laid out to see the nutrient requirement of this crop for higher production of seed yield and dye (Bixin) content under high rainfall and tropical climatic conditions.

* Corresponding author's present address: GSM Division, Indian Grassland and Fodder Research Institute, Jhansi 284003, Uttar Pradesh; E-mail: dr65sudhirkumar@yahoo.co.in
** Indian Grassland and Fodder Research Institute, Jhansi 284003
***Indian Instt. of Horticultural Research, Bengaluru

MATERIALS AND METHODS

The experiment was conducted during 2002-07 at Central Horticulture Experiment Station, Chettalli, Kodagu, Karnataka. The seedlings of annatto were planted at 6 m × 6 m spacing in main experimental field during 2002 and all the plants came into flowering in 2004. The location experiences tropical climate with heavy rainfall. The soil was sandy clay loam, medium in available N (339 kg/ha), low in P (9.2 kg/ha) and high in k (621 kg/ha) with pH of 6.41 and organic carbon (1.4%) The experiment was laid out in randomized block design replicated twice. From 2003 onward, seventeen different combinations of nitrogen, phosphorus and potash including control were imposed. Four doses of each N (20, 40, 60 and 80 g/plant/year of tree age), K_2O (30, 60, 90 and 120 g/plant/year of tree age) and constant dose of P_2O_5 (20 g/plant/year of tree age) were used in the experiment. The annual dose of fertilizer in the form of urea, single super phosphate and muriate of potash were given in two splits - the half dose of nitrogen and full dose of phosphorus and potash were applied before onset of monsoon and the remaining half dose of nitrogen was applied after the recession of monsoon. The trees were grown under humid tropical conditions with uniform cultural practices except the fertilizer rates. Annatto capsules were collected every year for computing total crop and seed yield per plant. Then seed samples were collected treatmentwise from which bixin content was analyzed by the method elucidated by Verissimo *et al*. (8).

After collecting the information on seed yield and analyzing the bixin content the data were pooled to get cumulative seed yield and bixin content, and then second order response surface was fitted for the annual and cumulative seed yield and bixin content as a function of the nutrient levels based on the tree age, with the help of which the doses of major nutrients for maximum seed yield and bixin content in terms of kilogram and percent were derived. The Response Surface Methodology (RSM) is a sequential form of experimentation used to optimize response variable (dependent variable) made of a statistical model of different explanatory variables. Introduced by Box and Wilson (2), this method is a collection of techniques that were developed as a means to find optimum settings of input factors or design variables that optimize or maximize, minimize or target measured response or outcome variables. The details regarding the methodology for developing RS models followed for computing are elucidated by Montgomery (4).

RESULTS AND DISCUSSION

Result on seed yield with regards to nutrition is presented in Table 1. The seed yield (kg/plant) was significantly influenced by different treatment combinations in all the three years. In the year 2005-06, treatment T_9 (80 g N + 40 g P_2O_5 + 60 g K_2O/pl/year) had recorded maximum seed yield (0.995 kg), which was at par with all the treatments except control. In 2005-06, treatment T_7 (80 g N + 60 g P_2O_5 + 150 g K_2O/pl/year) had recorded significantly higher seed yield (1.384 kg /plant) than all other treatments, whereas in the year 2006-07, it was maximum in treatment T_{16} (140 g N + 80 g P_2O_5 + 210 g K_2O/pl/year), *i.e.*, 2.674 kg /plant, which was significantly higher than other treatments except T_2, T_5, T_6, T_9 and T_{10}. The findings is in conformity with those of Biezen *et al.* (1) who have reported that the first batch of seed yield (IIIrd year) is limited to one kilogram, but in the next three years the total amount grows with one additional kilogram each year.

Result on bixin percent was analyzed with regards to nutrition and is presented in Table 2. In 2004-05, the bixin percent was found maximum (2.59%) in treatment T_{16} (100 gN + 40 g P_2O_5 + 150 g K_2O/pl/year) that was at par with the treatment T_1, T_2, T_5, T_6, T_7, T_9, T_{11}, T_{13}, T_{14} and T_{15}. In 2005-06 again it was significantly higher (2.39%) in treatment T_{16} (120 g N + 60 g P_2O_5 + 180 g K_2O/pl/year) than T_3, T_4, T_8, T_{10}, T_{12}, T_{15} and T_{17}, whereas in 2006-07, treatment T_9 (120 g N + 80 g P_2O_5 + 120 g K_2O/pl/year) has recorded

Table 1. Seed yield (kg/plant) of annatto in relation to nutritional status.

Treatment*	Seed yield (kg/plant)		
	2004-05	2005-06	2006-07
T_1	0.811	0.660	1.827
T_2	0.824	0.477	2.403
T_3	0.618	0.451	1.701
T_4	0.665	0.598	1.619
T_5	0.903	0.592	2.025
T_6	0.758	0.672	1.915
T_7	0.581	1.384	1.817
T_8	0.847	0.833	1.623
T_9	0.995	1.092	2.122
T_{10}	0.702	0.551	2.033
T_{11}	0.547	0.799	1.746
T_{12}	0.555	0.577	1.533
T_{13}	0.686	0.547	1.870
T_{14}	0.818	0.496	1.705
T_{15}	0.909	0.821	1.908
T_{16}	0.639	0.680	2.674
T_{17}	0.472	0.197	1.019
CD (P = 0.05)	0.449	0.181	0.936

*$T_1N_1K_1$(20 + 30 g/ plant); T_2, N_1K_2 (20 + 60); T_3, N_1K_3 (20 + 90); T_4, N_1K_4 (20 + 120); T_5, N_2K_1 (40 + 30); T_6, N_2K_2 (40 + 60); T7, N_2K_3 (40 + 90); T8, N_2K_4 (40 + 120); T_9, N_3K_1 (60 + 30); T_{10}, N_3K_2 (60 + 60); T_{11}, N_3K_3 (60 + 90); T_{12}, N_3K_4 (60 + 120); T_{13}, N_4K_1 (80+30); T_{14}, N_4K_2 (80 + 60); T_{15}, N_4K_3 (80 + 90); T_{16}, N_4K_4 (80 + 120); T_{17}, Control applied in first and every year an increased dose of 20 and 30 g N and K/plant was added in treatments, respectively.

Table 2. Bixin percent of annatto in relation to nutritional status.

Treatment	Bixin (per cent)		
	2004-05	2005-06	2006-07
T_1	2.35	2.17	2.34
T_2	2.25	2.08	2.11
T_3	2.11	1.95	2.32
T_4	2.16	1.99	2.24
T_5	2.34	2.16	2.34
T_6	2.22	2.05	2.15
T_7	2.41	2.22	2.29
T_8	2.21	2.04	2.35
T_9	2.39	2.21	2.42
T_{10}	2.13	2.30	2.17
T_{11}	2.24	2.07	2.15
T_{12}	2.17	2.01	2.29
T_{13}	2.41	2.23	2.26
T_{14}	2.22	2.05	2.33
T_{15}	2.48	1.97	2.27
T_{16}	2.59	2.39	2.29
T_{17}	2.11	1.95	2.08
CD (P = 0.05)	0.37	0.34	0.23

significantly higher bixin content (2.42%) than T_2, T_6, T_{10}, T_{11} and T_{17}. This result is supported by the findings of Verissimo *et al.* (8) who have reported that the presence of around 2.6% of bixin is considered to be a reasonable amount.

For different levels or treatment combinations of N and K for each year, as a preliminary work, the data was subjected to two-way analysis of variance. Further, with a view to find out the optimum dose of N and K combination with a fixed P_2O_5, which could result in optimum bixin percent, second order response surface models was fitted and the results are presented in Table 3 (for seed yield) and Table 4 (for bixin content).The RSM analysis results revealed (Table 3) that at the end of 2004-05, 75.98 g/plant of N and 72.42 g/plant of K_2O (with fixed P_2O_5 of 40 g/plant) was found to be the optimum dose which resulted to 1.41 kg/plant as optimum seed yield.

Table 3. Results of RSM for seed yield (kg/plant).

Year	RS model	N (g/plant) optimum as per SORD	K_2O (g/plant) optimum as per SORD	Optimum seed yield by substituting optimum N & K_2O
2004-05	$Y = 1.7804 - 0.0025\ N - 0.0071\ K + 0.0000358\ N^2 + 0.00004\ K^2 + 0.0000186\ NK$	75.98	72.42	1.409
2005-06	$Y = 0.51 + 0.04936\ N - 0.00064\ K - 0.000273\ N^2 - 0.0000037\ K^2 + 0.0000045\ NK$	91.528	141.811	2.816
2006-07	$Y = 7.02392 - 0.0581\ N - 0.0217\ K + 0.0001356\ N^2 + 0.0000055\ K^2 + 0.00018486\ NK$	101.93	124.51	2.235
Generalized	$Y = 3.62 - 0.000159\ N - 0.01\ K + 0.0000693\ NK - 0.0000446\ N^2 + 0.0000139\ K^2$	103.15	134.94	2.99

Table 4. Results of RSM for bixin content (%).

Year	RS Model	N (g/plant) optimum as per SORD	K_2O (g/plant) optimum as per SORD	Optimum bixin content by substituting optimum N & K_2O
2004-05	Y = 3.9-0.018N-0.012K + 0.00007 NK + 0.00007 N^2 + 0.00004 K^2	76.07	88.75	2.658
2005-06	Y = 2.99 + 0.002N -0.011 K + 0.000045 NK-0.0000 33 N^2 + 0.000036 K^2	117.91	99.35	2.53
2006-07	Y = 3.6 + 0.00009 N-0.013 K-0.000003 NK + 0.000003 N^2 + 0.00005 K^2	89.49	131.84	2.756
Generalized	Y = 2.9 + 0.00091 N-0.006 K + 0.000019 NK-0.0000169 N^2 + 0.000016 K^2	102.81	134.06	2.6

Similarly, in the year 2005-06, 91.53 g/plant of N and 141.8 g/plant of K_2O (with fixed P_2O_5 of 60 g/plant) were found to be the optimum dose, which resulted to 2.82 kg/plant as optimum seed yield. For the last year of experimentation (2006-07), 101.93 g/plant of N and 124.51 g/plant of K_2O (with fixed P_2O_5 of 80 g/plant) were found to be the optimum dose, which resulted to 2.24 kg/plant as optimum seed yield. As a generalization, the optimum dose of N and K_2O (with fixed P_2O_5) for optimum seed yield (2.99 kg/plant) would be 103.15 and 134.94 g/plant, respectively (Fig. 1).

Perusal of the results in Table 4 revealed that 76.07 g /plant of N and 88.75 g /plant of K (with fixed P_2O_5 dose) is found to be the optimum dose (for the year 2004-05), which resulted to 2.658% as optimum bixin content. Similarly, for the year 2005-06, 117.91 g /plant of N and 99.35 g/plant of K_2O (with fixed P_2O_5 dose) is found to be the optimum dose, which resulted to 2.53% as optimum bixin content. For the last year of experimentation, 89.49 g /plant of N and 131.84 g /plant of K_2O (with fixed P_2O_5 dose) was found to be the optimum dose, which resulted into 2.756% bixin content. As a generalization, the optimum dose of the nutrients (with fixed P_2O_5) would be 102.81 g /plant of N and 134.06 g/plant of K_2O for the optimum (2.6%) bixin content (Fig. 2).

It was concluded that the optimum dose of N and K_2O (with fixed P_2O_5) for optimum seed yield (2.99 kg /plant) would be 103.15 and 134.94 g /plant, respectively and for optimum (2.6%) bixin content the dose would be 102.81 g /plant of N and 134.06 g / plant of K_2O.

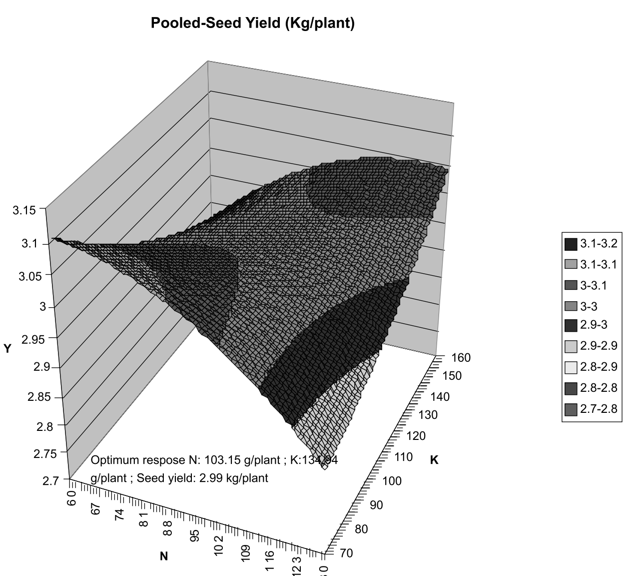

Fig. 1. Response surface graph for seed yield (kg/plant) generalized.

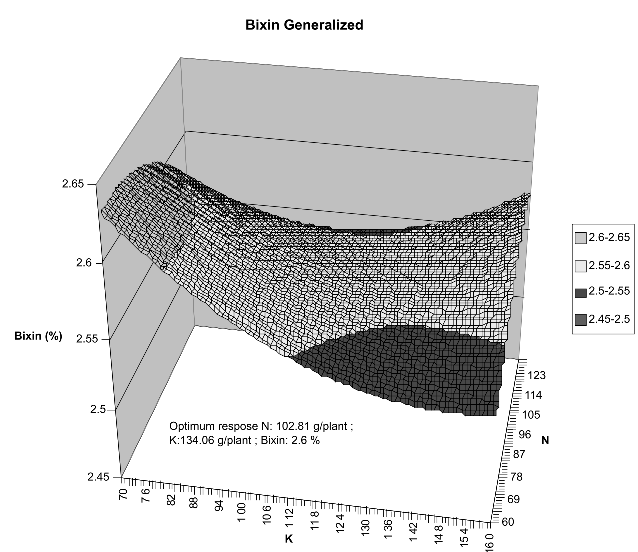

Fig. 2. Response surface graph for bixin content (%) generalized.

ACKNOWLEDGEMENTS

The authors are grateful to the Director, Indian Institute of Horticultural Research, Bengaluru for providing the research facilities.

REFERENCES

1. Biezen, van de R.W., Van Doren, J., Ferguson, B., Teeuw, J. and Van de Woerd, Y. 2006. Seeds of Life. *'t Arium, Amesfoort*, the Netherlands.
2. Box, G.E.P. and Wilson, K.B. 1951. On the experimental attainment of optimum conditions. *J. Royal Stat. Soc.* **13**: 1-45.
3. Maximo, C.G. Jr. and Singh, J. 1984. *Statistical Methods in Food and Consumer Research.* Academic Press Inc., Orlando, Florida, pp. 214-72.
4. Montgomery, D.C. 2001. *Design and Analysis of Experiments* (5th Edn.), John Wiley & Sons Inc., New York.
5. Ramachander, P.R., Shikhamany, S.D. and Rao, G.S.P. 1990. Alternative strategies for pooled analysis in perennial crop trials with special reference to grapevines. *Indian J. Hort.* **47**: 194-200.
6. Reddy, Y.T.N., Kurian, M., Kohli, R.R., Rao, G.S.P., Ramachander, P.R. and Singh, Gorakh. 1998. Requirement of major nutrients for 'Alphonso' mango (*Mangifera indica). Indian J. Agric. Sci.* **68**: 652-56.
7. Sharma, S.C., Mehrotra, N.K., Gupta, M.R. and Singh, H. 1990. Game theory approach to nutritional trial on sweet orange cv. Jaffa. *Punjab Hort. J.* **30**: 9-12.
8. Verissimo, S.A., Oliveira, E.L., Ladchumananandasivam, R., Cruz, L.P.R., Praxedes, G.F. and Aquino. M.S. 2003. Extraction, characterization and application of annatto dye in the dyeing of natural fibers. E-mail: silvagneradolpho@eq.ufrn.br.

Received : July, 2010; Revised : December, 2011; Accepted : February, 2012