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CORRELATION AND PATH ANALYSIS STUDIES FOR GROWTH AND YIELD CONTRIBUTING TRAITS IN GUAVA AS AFFECTED BY MICRONUTRIENTS

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ABSTRACT

The field experiment was carried out at Horticulture Research Station, Mondouri, (West Bengal) with guava (Psidium guajava L.) variety "Allhabad Safeda" during February-August (rainy season or ambe bahar crop) of 2013-2015. Experimental trees were subjected to eight sole and combined micronutrient treatments composed of boron, zinc and copper. The results revealed that the treatment T_8 (0.2% H_3 BO_3 + 0.5% $ZnSO_4$ + 0.5% Cu SO_4) produced the highest number of shoots/meter branch (14.95), new leaves/shoot (14.54). leag area (53.51 cm^2) over other treatments. The highest fruit yield (12.63 kg $tree^{-1}$ and 7.90 t ha^{-1}), shoots/meter branch (14.95), new leaves/shoot (14.54), leaf area (53.51 cm^2) were obtained with foliar application of 0.2% H_3BO_3 + 0.5% $ZnSO_4$ + 0.5% $CuSO_4$. Fruit yield, as dependent variable, showed the positive significant correlation with all the independent variables except number of shoots /meter branch. Fruit retention percentage revealed the highest degree of correlation followed by number of fruits /tree, length of shoots, new leaves /shoot, leaf fresh weight, leaf area and leaf dry weight. Fruits /tree had highest direct and positive effect on fruit yield of guava followed by fruit retention percentage and leaf fresh weight. Path analysis revealed that fruit retention percentage and fruits /tree had highest direct effect on fruit yield. Thus these two indices can be selected for yield improvement in guava especially with respect to fruit yield and nutrient management.

Key words: Guava, micronutrient, fruit yield, correlation, path analysis.

INTRODUCTION

Guava (*Psidium guajava* L.) is one of the well known edible tree fruits grown widely in more than sixty countries throughout the tropical and subtropical regions of the world (Patel *et al.,* 2015). In India, guava stood in fourth position in terms of area and production after mango, banana and citrus. The fruits are delicious, rich in vitamin 'C', pectin and minerals like calcium, phosphorus and iron (Patra *et al.,* 2004). Besides, high concentrations of pectin in guava fruit may play a significant role in the reduction of cholesterol and thereby decrease the risk of cardiovascular disease. The agro-climatic condition of the West Bengal is quite suitable for commercial cultivation of guava. But a serious depletion in soil micronutrient status has been reported from different parts of West Bengal. The main reasons for the occurrence of micronutrient deficiency is the adoption of intensive cropping with gradual shift to use of high analysis chemical fertilizers instead of organic and conventional plant nutrients i.e. farm yard manure, composts etc. Micronutrients can be applied to plants by soil and foliar application, but foliar application of micronutrients is more effective than soil application (Zaman and Schumann, 2006). Zinc is one of the eight essential trace elements or micronutrients for the normal healthy growth and reproduction of crop plants (Keram *et al.,* 2014). The boron proved its importance in tree physiology through much higher requirement in reproductive growth than for vegetative growth and increases flower production and retention, pollen tube elongation and germination and seed and fruit development. Copper (Cu) is an essential element for plant as it plays significant role in many alterations of plant cells and inhibition of enzymatic activities (Teisseire and Guy, 2000), changes in respiration, photosynthetic CO_2 fixation and photosynthetic pigments by increasing oxidation of chloroplast membranes (Hattab *et al.,* 2009). Fruit production, a complex dependent character is contributed by several component characters. Direct selection for fruit yield is often not very effective and thus indirect selection of some associated component traits may be useful (Hassan *et al.,* 2013). Phenotypic correlations of yield with growth attributes and path analysis become useful for crop improvement programmes to select the desirable types (Ahmed and Kamaluddin, 2013).

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Accordingly, the present investigation was carried out to study the association of fruit yield attributes and yield of guava as influenced by micronutrient application.

MATERIALS AND METHODS

Field experiment was conducted at Horticulture Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, West Bengal (22º 56′ N latitude and 88º 31′ E longitude with an elevation of 9.75 m above mean sea level) with guava variety "Allhabad Safeda" during February-August (rainy season or *ambe bahar* crop) of 2013-2015. The average fluctuation of maximum and minimum temperature between 37.5° – 29.7° C and 27.2° – 16.6° C, respectively ; relative humidity between 97.86 and 34.00%; rainfall of 1231.7 mm (45 rainy days) and maximum bright sunshine of 167.61 hours were recorded during the experimental period (February to August of 2013–15). The soil of the experimental site was sandy clay loam in texture, neutral in reaction (pH 6.9), medium in organic carbon (5.5 g ka^{-1}); high in available K (287 kg ha^{-1}), available P (26 kg ha^{-1}) and available copper (1.61 mg kg^{-1}); and low in available N (168 kg ha^{-1}), available B (0.06 mg kg^{-1}) and available Zn (0.67 mg kg^{-1}). Eight micronutrient treatments [T_1 - Control (water spray only), T_2 - 0.2% H_3BO_3, T_3 - 0.5% $ZnSO_4$, T_4- 0.5% $CuSO_4$, T_5 - 0.2% H_3BO_3 + 0.5% $ZnSO_4$, T_6 - 0.2% H_3BO_3 + 0.5% $CuSO_4$, T_7 - 0.5% $ZnSO_4$ + 0.5% $CuSO_4$ and T_8 - 0.2% H_3BO_3 + 0.5% $ZnSO_4$ + 0.5% $CuSO_4$ @ 0.5%], were laid down in a complete randomized block design with three replications. The five year aged guava trees planted at 4m × 4m spacing were also fertilized with the recommended dose of NPK (250:375:250 g N, P_2O_5 and K_2O per plant, respectively). Urea, single superphosphate and muriate of potash were the source of N, P and K, respectively while boric acid (17% B,), zinc sulphate (21% Zn) and copper sulphate (24% Cu) were used as the sources of B, Zn and Cu, respectively. Micronutrient fertilizers were sprayed twice according to the treatment combinations, one at flowering (3rd week of March) and second spray one month after first spray (last week of April) using a hand operated knapsack sprayer. Vegetative growth parameters like shoots/ meter branch and new leaves/ shoot, length of shoots (cm), leaf area (cm^2), leaf fresh and dry weight (g) were taken on late March by selecting four main branches of similar diameters (4.0 cm) around the periphery of each tree during the experimental year. Ten shoots of the spring flush from each selected branch were tagged and plant growth biometric observations were taken following standard protocols (Sau *et al.,* 2016). For estimating leaf area, planimeter was used. The percentage of fruit retention was computed by using the following formula:

$$\text{Fruit retention\%} = \frac{\text{No. of retained fruits (At harvest)}}{\text{No. of fruits at 30 DAF (Days after fruit set)}}$$

All the fruits from individual tree were counted manually to record the total number of fruits/ tree. The total fruits harvested (in 2-3 intervals) from each tree was measured with weighing balance to obtain the fruit yield per tree and expressed in kilograms. Value of fruit yield from each tree was multiplied by number of plants per hectare and recorded as fruit yield per hectare in tonnes.

RESULTS AND DISCUSSION

Fruit yield attributes and yield

Micronutrients are known to accelerate the metabolic activities of plants, thereby mobilizing more amounts of photosynthates from source to sink thus it ultimately improves yield attributes like shoots/ meter branch, length of shoots, new leaves/ shoot, leaf area and both the leaf fresh and dry weight over control. Data (Table 1), revealed that among the different treatments, T_8 (0.2% H_3BO_3 + 0.5% $ZnSO_4$ + 0.5% $CuSO_4$) recorded highest number of shoots/ meter branch (14.95), new leaves/ shoot (14.54), leaf area (53.51 cm^2) while T_5 (0.2% H_3BO_3 + 0.5% $ZnSO_4$) produced highest length of shoots (21.42 cm), leaf fresh (19.10 g) and dry weight (7.09 g) as well as fruit retention percentage (52.89%).

Table 1: Effect of micronutrients on plant growth and yield attributes of guava cv. Allahabad Safeda

Treatments	Shoots /meter branch	Length of shoots (cm)	New leaves /shoot	Leaf area (cm^2)	Leaf fresh weight (g)	Leaf dry weight (g)	Fruit retention percentage
T_1 – Control (Water spray only)	11.01	16.58	10.06	47.04	15.21	5.55	42.32
T_2 – 0.2% H_3BO_3	11.50	20.58	13.33	52.26	16.58	5.77	50.27
T_3 – 0.5% $ZnSO_4$	12.67	19.28	11.64	49.83	18.45	6.60	50.99
T_4 – 0.5% $CuSO_4$	11.55	19.08	12.57	49.37	16.73	6.60	47.64
T_5 – 0.2% H_3BO_3 + 0.5% $ZnSO_4$	11.90	21.42	13.68	50.86	19.10	7.09	52.89
T_6 – 0.2% H_3BO_3 + 0.5% $CuSO_4$	11.51	20.06	11.93	50.61	16.15	5.82	47.63
T_7 – 0.5% $ZnSO_4$ + 0.5% $CuSO_4$	13.27	21.32	12.77	49.47	15.93	6.13	48.79
T_8 – 0.2% H_3BO_3 + 0.5% $ZnSO_4$ + 0.5% $CuSO_4$	14.95	20.95	14.54	53.51	18.30	6.80	52.28
SEm±	0.65	1.08	0.61	2.66	0.53	0.24	1.80
CD (p=0.05)	1.98	NS	1.86	NS	1.60	0.74	5.47

NS, Non-Significant

It is evident (Table 2), that irrespective of single or combined micronutrient application, fruits per tree were significantly ($p \leq 0.05$) increased over the control (water spray only). The maximum fruits per tree (133.18) was obtained from trees treated with T_5 (0.2% H_3BO_3 + 0.5% $ZnSO_4$) with an increase of 24.39% over control (water spray only) which was statistically at par ($p \leq 0.05$) with T_8, T_6 and T_7 (130.06, 129.91 and 126.04, respectively). The highest fruit yield (12.63 kg/tree and 7.90 t/ha) was obtained with foliar application of 0.2% H_3BO_3 + 0.5% $ZnSO_4$ + 0.5% $CuSO_4$ which was statistically at par ($p \leq 0.05$) with T_5 (H_3BO_3 @ 0.2%+ $ZnSO_4$ @ 0.5%) and resulted in 37.37% higher fruit yield than control.A positive effect on yield and yield attributes by applying boric acid, zinc sulphate and copper sulphate either singly or in combinations was reported by Balakrishnan (2000), Chaitanya *et al.,* (1997) in guava and Chahil *et al.,* (1996) in plum. An increase in photosynthetic activity of leaves and consequently in the yield as a result of boron, zinc and copper seems to be obvious as these nutrients actively involved in the plant metabolism, enzyme regulation thus maintaining optimum balance of plant nutrients and growth substances in the plant cell.

Table 2: Effect of micronutrients on yield of guava cv. Allahabad Safeda

Treatments	Fruits /tree	Fruit yield (kg/tree)	Fruit yield (t/ha)
T_1 – Control (Water spray only)	107.06	9.20	5.75
T_2 – 0.2% H_3BO_3	115.01	10.92	6.82
T_3 – 0.5% $ZnSO_4$	121.11	11.44	7.15
T_4 – 0.5% $CuSO_4$	114.11	10.39	6.50
T_5 – 0.2% H_3BO_3 + 0.5% $ZnSO_4$	133.18	12.31	7.69
T_6 – 0.2% H_3BO_3 + 0.5% $CuSO_4$	129.91	11.27	7.05
T_7 – 0.5% $ZnSO_4$ + 0.5% $CuSO_4$	126.04	11.10	6.95
T_8 – 0.2% H_3BO_3 + 0.5% $ZnSO_4$ + 0.5% $CuSO_4$	130.06	12.63	7.90
SEm±	3.68	0.45	0.24
CD (p=0.05)	11.15	1.37	0.73

Relationship among independent and dependent yield contributing variables

Most of the variables presented in the phenotypic correlation matrix exhibited the significant positive relationship among the variables (Table 3). Fruit yield as dependent variable showed the positive significant correlation with all the independent variables except number of shoots /meter branch. The fruit retention percentage revealed the highest degree of correlation (R^2 = 0.927) with fruit yield followed by fruits /tree, length of shoots, new leaves/shoot, leaf fresh weight, leaf area and leaf dry weight. All the variables were significant at 1% level of significance with fruit yield except fruit retention percentage and fruits /tree as they were significant at 5% level of significance with fruit yield. The matrix also points out the different degrees of significant correlation coefficients among the independent variables. The correlation of independent variables revealed that new leaves /shoot and length of shoots, leaf area and length of shoots, leaf area and new leaves /shoot, fruit retention percentage and length of shoots, fruit retention percentage and new leaves /shoot, fruit retention percentage and leaf area, fruit retention percentage and leaf weight (fresh and dry), fruits /tree and length of shoots had very high positive and significant correlation among themselves.

Table 3: Phenotypic correlation matrix for yield and related traits of guava cv. Allahabad Safeda

Parameters	Shoots /meter branch	Length of shoots	New leaves / shoot	Leaf area	Leaf fresh weight	Leaf dry weight	Fruit retention percentage	Fruits /tree
Length of shoots	0.519							
New leaves /shoot	0.621	0.864**						
Leaf area	0.585	0.740*	0.882**					
Leaf fresh weight	0.447	0.505	0.601	0.552				
Leaf dry weight	0.497	0.499	0.623	0.397	0.893**			
Fruit retention percentage	0.568	0.838**	0.844**	0.798*	0.867**	0.758*		
Fruits /tree	0.534	0.809*	0.636	0.58	0.591	0.572	0.720*	
Fruit yield	0.691	0.833*	0.827*	0.810*	0.813*	0.731*	0.927**	0.892**

***Correlation significant at the 0.01 level (2-tailed), *Correlation significant at the 0.05 level (2-tailed)*

On the other hand, rest of the independent variables had non-significant and poor correlation among themselves. It is obvious from the data (Table 4) that fruits /tree had highest direct and positive effect on fruit yield of guava followed by fruit retention percentage and leaf fresh weight. Perusal of indirect effects of fruits /tree revealed that it also had a high degree of indirect effect via length of shoots and fruit retention percentage. So, all the parameters were positively correlated with fruit yield whereas path analysis expresses the negative direct effects of length of shoots and leaf dry weight. Although, these two parameters had negative direct effect on fruit yield of guava but their total correlation with fruit yield recorded positive value through positive indirect effects. So, the standard regression equation was:

$$Y=0.12X_1 - 0.220X_2 + 0.136X_3 + 0.122X_4 + 0.145X_5 - 0.071X_6 + 0.373X_7 + 0.532X_8$$

Here in this equation, Y is the fruit yield of guava and X_1, X_2, X_3, X_4, X_5, X_6, X_7 and X_8 are the shoots /meter branch, length of shoots, new leaves /shoot, leaf area, leaf fresh weight, leaf dry weight, fruit retention percentage and fruits /tree, respectively.

Table 4: Estimates of direct and indirect effects on fruit yield and related traits of guava cv. Allahabad Safeda

Parameters	Shoots /meter branch	Length of shoots	New leaves /shoot	Leaf area	Leaf fresh weight	Leaf dry weight	Fruit retention percentage	Fruits /tree	Total correlation with fruit yield
Shoots/meter branch	***0.124***	-0.114	0.084	0.071	0.065	-0.035	0.212	0.284	0.691
Length of shoots	0.064	***-0.220***	0.117	0.090	0.073	-0.035	0.313	0.431	0.833
New leaves/shoot	0.077	-0.190	***0.136***	0.108	0.087	-0.044	0.315	0.339	0.827
Leaf area	0.072	-0.163	0.120	***0.122***	0.080	-0.028	0.298	0.309	0.810
Leaf fresh weight	0.055	-0.111	0.081	0.067	***0.145***	-0.063	0.324	0.315	0.813
Leaf dry weight	0.062	-0.110	0.084	0.048	0.130	***-0.071***	0.283	0.305	0.731
Fruit retention percentage	0.070	-0.184	0.114	0.097	0.126	-0.054	***0.373***	0.383	0.927
Fruits /tree	0.066	-0.178	0.086	0.071	0.086	-0.041	0.269	***0.532***	0.892

Residual effect: 0.0025; Bold-Italics figures represent direct effects and others indirect effects

Though, the fruit yield showed different correlation coefficients with each of the independent variables, however, simple correlation should not be interpreted as having causal relationship between two variables (Gomez and Gomez, 1984). Correlation study measures the mutual association without definite cause. So correlation study may not always provide a true picture of the association. The association become complex when many correlated characters are affecting a particular variable. Hence, a path coefficient analysis enables us to evaluate the direct effect of one cause on an effect and its indirect effect through other causes (Kumar *et al.,* 2013). Path analysis in the present study revealed that the correlation of length of shoots and leaf dry weight with fruit yield was through positive indirect effect of fruit retention percentage and fruits /tree. High correlation of fruit retention percentage with fruit yield was due to positive indirect effect of fruits /tree. Thus it can be inferred that fruit retention percentage and fruits /tree both these parameters were under genotypic control. High direct effect of a character on yield indicates that it was controlled by additive type of gene action (Patel *et al.,* 2015).

On the basis of study, it can be concluded that application of micronutrient fertilizers (0.2% H_3BO_3 + 0.5% $ZnSO_4$ + 0.5% $CuSO_4$) along with RDF of NPK is required as a balanced plant nutrition programme to maximize the yield of guava (cv. Allahabad Safeda) in *Inceptisol* of the Gangetic plains of West Bengal, India. Hence, fruit retention percentage and fruits /tree had highest direct effect on fruit yield. These two indices may be selected for yield improvement in guava especially with respect to fruit yield and nutrient management.

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