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Correlation studies of different physico-morphological characters in citrus rootstock genotypes with fruit yield under Vidarbha region

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Abstract
The aim of this study was to find out relationship between yield and yield components of citrus rootstock genotypes and ultimately the development of new genotypes with more yield comprising of important horticultural traits. Thirty genotypes of citrus rootstocks belonging to four species *viz*., *C. jambhiri*, *C. limonia, C. pseudolimon* and *C. macrophylla* were collected from Akola, Nagpur and Amravati districts and analysed for 43 physico-morphological characters. Correlation study revealed that the correlation of fruit yield with fruit weight (0.587), pomace weight (0.564), fruit volume (0.562), leaf area (0.560), number of fruits tree^{-1} (0.502), leaf lamina length (0.490) and leaf lamina width (0.468) was highly significant and in positive direction. It was also positively and significantly correlated with stem girth (0.447), petal width (0.451), chlorophyll content (0.423), fruit diameter (0.382) and weight of 20 seeds (0.377), whereas significant and negatively correlated with non-reducing sugars (-0.429) and total sugars (-0.400).

Keywords: Correlation, citrus, morphology, rootstocks, yield

Introduction

Citrus is the most important group of fruit commercially cultivated on a world-wide basis and is grown wherever, the climate is suitable. It is widely grown in most areas with suitable climates tropical, subtropical and borderline subtropical and temperate [14]. The genus *Citrus* belongs to the subtribe Citrineae, the tribe Citreae within the subfamily Aurantioideae of the Rutaceae family [25]. The other economically important genera of this family are *Poncirus* and *Fortunella*.

Fruit growers depend primarily on yield and fruit quality to determine their net income. Their ability to achieve profitable levels of productivity and fruit quality is largely a matter of the orchard system selected and its successful management [12]. An orchard system has been defined as "the integration of all the horticultural factors involved in establishing and maintaining a planting of fruit trees" [5]. Among a multitude of such factors is the rootstock. Until the mid- 1800s, citrus was grown primarily as seedlings. It is generally known that the outburst of phytophthora foot root and citrus tristeza virus were apparently responsible for creating the initial interest in citrus rootstocks and changing the direction of citriculture [7]. Further, importance of rootstock also relates to adaptability, root distribution, mycorrhizal dependence, longevity and fruit quality apart from resistance to pest and diseases which largely determines the profitability of citriculture [22]. Rootstock research in the beginning involved only a few rootstocks primarily rough lemon, sour orange, trifoliate orange, sweet orange and occasionally grapefruit and Cleopatra mandarin. Now the use of rootstock in commercial citrus production is well established. It is well-known from decades of experience that citrus rootstocks bring many advantages and profitability to commercial enterprise. In some instances, citrus rootstocks are the sole determining element that allows citrus to be grown in particular circumstances. Yet, despite their popularity and necessity, every rootstock has one or more undesirable traits that preclude its universal use. Those limitations have elevated the need for dependable new rootstocks [7]. India, a natural home of several citrus species harbours vast reservoir of diverse types and forms ranging from oranges, mandarins, pummelo, grapefruit, lime and lemon, wild and semi wild species and other related genera. Elucidating relationship and diversity amongst these varied reservoir with respect to tree

structure, canopy development, shape of canopy, features of fruits, diseases and insect resistance as well as their utility as rootstock is important for developing breeding strategies, conserving biodiversity and improving breeding efficiency.
Information on the correlation and linkage among different horticultural characteristics is of primary importance in the field of crop improvement. The main objective of this research was to study the correlation among different agronomic and horticultural characteristics of citrus rootstocks. Fruit yield is a complex trait with polygenic inheritance, and correlation studies provide information that selection for one character results in progress for all positively correlated characters. The adequate knowledge of association between yield and its contributing traits has a great importance in plant breeding. For any crop, to setup a suitable breeding programme, information about interrelationship among and between yield contributing characters is necessary. Correlation would provide a true picture of genetic association among different traits [6]. The knowledge of correlation between yield and component characters and among the component characters themselves is essential for a rational and directed improvement of yield [19].

Materials and Methods

The study was carried out at Department of Horticulture, Dr. PDKV, Akola during 2014-2016. The material for present study consisted of 30 genotypes which were randomly selected from three locations *viz*., Akola, Amravati and Nagpur. Since the study is based on single plant observation, the samples for observations were collected from each direction i.e. East, West, North and South and each of these directions were considered as one replication. Further, the observed characteristics were subjected to Randomized Block Design (RBD) analysis. Observations *viz*., plant height, canopy spread, stem girth and ratio of leaf lamina length/ width were not considered for RBD analysis. The genotypes were of different age and no special cultural practices have been followed. Sampling of 20 leaves, 10 flowers, 20 fresh seeds and 20 fruits was carried out randomly from each selected tree. The morphological characteristics used to characterize and describe the rootstock genotypes were based on the descriptor prescribed for citrus by the International Plant Genetic Resource Institute [2], Rome; International Union for the Protection of New Varieties of Plant, Geneva [3] and Citrus resources (Citrus ID), USA [1]. Taking into consideration all the precautions reported in this respect, 43 quantitative physico-morphological characteristics were selected for the present investigation (simple correlation analysis). These quantitative characters are plant height (m), canopy spread (m), stem girth (cm), spine length on adult tree (mm), lamina length (mm), lamina width (mm), ratio of leaf lamina length/ width, petiole length (mm), leaf area $(cm)^2$, chlorophyll content (mg/g), pedicel length (mm), petal length (mm), petal width (mm), number of stamens, bud length (mm), bud width (mm), fruit length (mm), fruit diameter (mm), fruit weight (g $fruit^{-1}$), oil gland density (cm^{-2}), vesicle length (mm), number of segments, segment length (mm), segment breadth (mm), diameter of axis (mm), rind thickness (mm), weight of peel (g), pomace weight (g), number of fruits $tree^{-1}$, fruit volume (cc), juice content (%), yield (kg $plant^{-1}$), moisture (%), total soluble solids (^{0}Brix), titrable acidity (%), pH, ascorbic acid (mg/100g), reducing sugars (%), non-reducing sugars (%), total sugars (%), number of seeds $fruit^{-1}$, weight of 20 seeds (g) and germination per cent.
Fruit samples were analysed at Analytical Laboratory, Department of Horticulture, Dr. PDKV, Akola. Ascorbic acid content of fruit was determined by using 2, 6- dichlorophenol indophenol dye titration method [16]. Reducing, non-reducing and total sugars were estimated on fresh weight basis by using Lane and Eynon method with modification suggested by [18]. Acidity was determined by titrating with standard sodium hydroxide solution and expressed in per cent [18]. Total soluble solids were estimated by using digital refractometer (ATAGO, RX-7000α) and expressed in °Brix. Moisture percentage was determined with the help of Electronic Moisture Balance (Shimadzu MOC-120H) and was expressed in per cent. The pH of fruit juice was determined by using pH meter (Systronics µpH system 362). Pearson correlation was calculated by using SAS university edition version: university.cny.sas.com@sas:university-6p.2/6p.2.688de4662a09-1-1 between different plant growth, leaf, fruit, seed, and chemical and yield characters.

Results and Discussion

The knowledge of correlation is very useful in ascertaining the association of characters, so that proper evaluation on phenotypic characters could be made. The knowledge about the degree of association of such characters forms the basic requirement in identifying a desirable plant genotype. In present investigation, various quantitative characters were studied for 30 citrus rootstock genotypes. The nature and extent of association among them is discussed hereunder.
The correlation coefficients of 42 characters in citrus rootstocks with fruit yield are presented in Table 1 and illustrated with scatter plot matrix (Figure 1). It was found that most of the variables were not dependent on yield just few of them showed considerable relation. The maximum correlation value was observed in fruit weight followed by pomace weight and fruit volume that was expected because as the fruit weight increases the chance of getting more yield also increases. Number of fruits $tree^{-1}$ and leaf area also showed high correlation. Leaf lamina length, lamina width, stem girth, petal width, chlorophyll content, fruit diameter, weight of 20 seeds, bud width, fruit length, number of segments, segment length, non-reducing sugars and total sugars showed good correlation with yield and for remaining variables low degree of correlation was found. In genetic system, most of the characters are associated with each other and such association may be the product of some pleiotropic effects of gene, existence of two genes on the same chromosome, chromosomal segmental affiliation or due to environmental influences [20]. Therefore, information of character association between traits and yield component is important to select high yielding genotypes.
The critical perusal of the data on correlation study (Table 1) revealed that the correlation of fruit yield with leaf lamina length, leaf lamina width, leaf area, fruit weight, pomace weight, number of fruits $tree^{-1}$ and fruit volume was highly significant and in positive direction. It was also positively and significantly correlated with stem girth, chlorophyll content, petal width, fruit diameter and weight of 20 seeds. Certainly, larger leaf area must have resulted in more synthesis of photosynthates and their accumulation, which might be responsible for better growth.
These findings are in agreement with the report of [4] in *Galgal* genotypes wherein they observed positive and significant correlation of yield with fruit diameter and fruit weight. Moreover, they also observed significantly positive correlation of yield with fruit length, number of seeds and juice content which is not tallying with current outcomes.

Further, in pummelo genotypes [17] found positive correlation of yield with trunk diameter while they also stated that yield was not correlated with fruit quality characters such as per cent of pulp, thickness of rind, total soluble solids and titrable acidity that is in line with current findings. Highly significant and positive correlation of yield with the number of fruits tree^{-1} and breadth of fruit was recorded by [8] in sweet orange. In addition, [10] in pummelo stated that number of fruits tree^{-1}, fruit weight, diameter, rag weight had highly significant and positive correlation with yield, which is in consonance with present study. However, the remaining characters studied by them showing correlation with yield were fruit length, size of oil gland, diameter of axis, rind thickness, weight of pulp and ascorbic acid differed from the present outcomes. Further, [15] also noted highly significant positive correlation of yield with fruit volume and number of fruits per plant.

The negative and significant correlation was exhibited by non-reducing sugars and total sugars with yield contributing character. In apricot genotypes [9] stated negative correlation of yield contributing character (fruit weight) with sucrose content which is tallying with present readings. Negative and significant correlation of total sugars with yield was also stated by [10] in pummelo types which is in line with present outcome.

The characters *viz*., canopy spread, spine length on adult tree, ratio of leaf lamina length/ width, petiole length, petal length, number of stamens, bud length, bud width, fruit length, oil gland density, vesicle length, number of segments, segment length, segment breadth, weight of peel, juice content, moisture per cent, pH and number of seeds fruit^{-1} had positive but non-significant correlation [4]. Reported negative and significant while [13] stated negative and non-significant correlation of juice per cent with yield contributing characters, which are highly controversial with current results. Positive non-significant correlation of number of seeds fruit^{-1} with yield contributing character (fruit size) was found by [23] in hill lemon genotypes that is matching with current findings. Further, [21] and [24] revealed non-significant correlation of yield contributing character (fruit weight) with juice, pulp, peel per cent and number of articulates in acid lime and Baramasi lemon strains, which is in line with current findings [11]. Noted positive correlation between yield contributing character (fruit length/ width ratio) with seed number, which is in correspondence with present results. Similar outcome in pummelo genotypes were reported by [10] with characters *viz*., canopy spread, petiole wing length, petal length, flower bud length, bud width, segment breadth and number of seeds fruit^{-1}.

The plant height, pedicel length, diameter of axis, rind thickness, total soluble solids, titrable acidity, ascorbic acid and reducing sugars showed negative and non-significant correlation [10]. Noted negative and non-significant correlation of yield in pummelo genotypes with plant height, pedicel length and reducing sugars which is in consonance with present results [9]. Stated in apricot positive relationship between yield and reducing sugars while, [11] depicted positive correlation of yield contributing character with titrable acidity and total soluble solids in some lime and lemon accessions, which is differing from the findings of current study.

Therefore, the result of correlation studies of different characters in 30 citrus rootstock genotypes illustrated that due weightage be given to the parameters like leaf lamina length, leaf lamina width, leaf area, fruit weight, pomace weight, number of fruits tree^{-1}, fruit volume, stem girth, chlorophyll content, petal width, fruit diameter and weight of 20 seeds while selecting superior rootstock types plant height (PH), canopy spread (CS), stem girth (SG), spine length on adult tree (SLoAT), lamina length (LL), lamina width (LW), ratio of leaf lamina length/ width, petiole length (LL/LW), leaf area (LA), chlorophyll content (CC), pedicel length (PdL), petal length (PtL), petal width (PtW), number of stamens (NoSt), bud length (BL), bud width (BW), fruit length (FL), fruit diameter (FD), fruit weight (FW), oil gland density (OGD), vesicle length (VL), number of segments (NoSg), segment length (SL), segment breadth (SB), diameter of axis (DA), rind thickness (RT), weight of peel (PeW), pomace weight (PomW), number of fruits tree^{-1} (NoF), fruit volume (FV), juice content (JC), moisture (M), total soluble solids (TSS), titrable acidity (TA), pH, ascorbic acid (AA), reducing sugars (RS), non-reducing sugars (NRS), total sugars (TS), number of seeds fruit^{-1} (NoS), weight of 20 seeds (WS) and germination percent (GP).

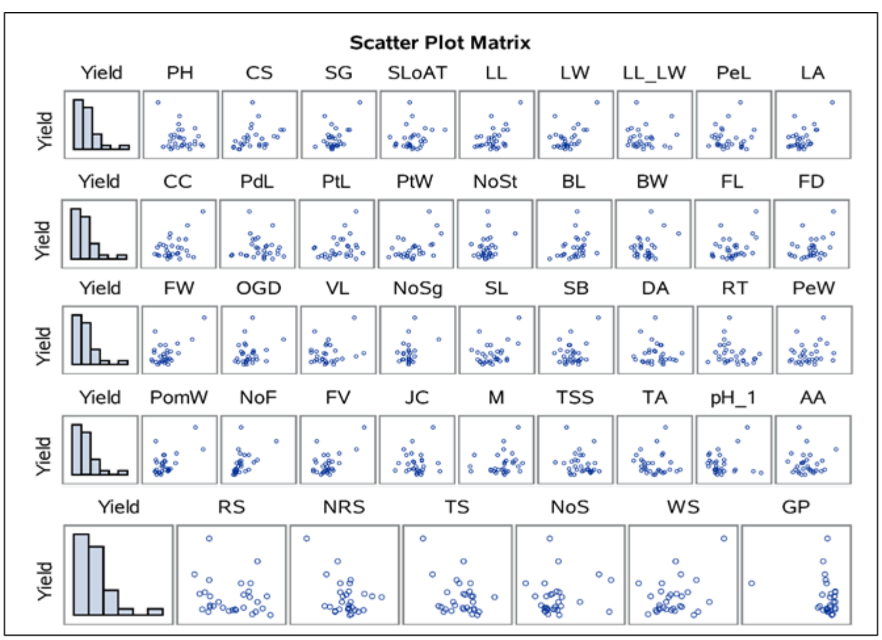

Fig 1: Scatter plot matrix of yield with 42 physico-morphological characters

Table 1: Correlation coefficients (r) of different characters in citrus rootstock genotypes with fruit yield for pooled mean

Sr. No.	Parameters/characters	Correlation coefficient (r)
1	Plant height (m)	-0.276
2	Canopy spread (m)	0.258
3	Stem girth (cm)	0.447*
4	Spine length on adult tree (mm)	0.191
5	Lamina length (mm)	0.490**
6	Lamina width (mm)	0.468**
7	Ratio of leaf lamina length/ width	0.031
8	Petiole length (mm)	0.027
9	Leaf area $(cm)^2$	0.560**
10	Chlorophyll content (mg/g)	0.423*
11	Pedicel length (mm)	-0.062
12	Petal length (mm)	0.276
13	Petal width (mm)	0.451*
14	Number of stamens	0.254
15	Bud length (mm)	0.267
16	Bud width (mm)	0.319
17	Fruit length (mm)	0.343
18	Fruit diameter (mm)	0.382*
19	Fruit weight (g $fruit^{-1}$)	0.587**
20	Oil gland density (cm^{-2})	0.220
21	Vesicle length (mm)	0.198
22	Number of segments	0.311
23	Segment length (mm)	0.355
24	Segment breadth (mm)	0.288
25	Diameter of axis (mm)	-0.097
26	Rind thickness (mm)	-0.236
27	Weight of peel (g)	0.211
28	Pomace weight (g)	0.564**
29	Number of fruits $tree^{-1}$	0.502**
30	Fruit volume (cc)	0.562**
31	Juice content (%)	0.052
32	Moisture (%)	0.224
33	Total Soluble Solids (^{0}Brix)	-0.209
34	Titrable acidity (%)	-0.053
35	pH	0.129
36	Ascorbic acid (mg/ 100g)	-0.020
37	Reducing sugars (%)	-0.184
38	Non-reducing sugars (%)	-0.429*
39	Total sugars (%)	-0.400*
40	Number of seeds $fruit^{-1}$	0.112
41	Weight of 20 seeds (g)	0.377*
42	Germination percent	-0.197

*Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

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