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Path and factor analysis of roselle (*Hibiscus sabdariffa* L.) performance

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ABSTRACT

Roselle is known for delicacy and also for medicinal properties. There is only limited information available on genetics and breeding of its economic traits. In this experiment, roselle were grown as a split–split plot based on a randomized complete-block design with three replications during 2015, at the experimental station of University of Birjand in Sarayan, Iran. Treatments consisted of three factors, including irrigation management (two levels), humic-acid application (two levels) and mycorrhizal inoculation (three levels). Sixteen related traits were recorded. After data collection, correlation analysis, regression and path analysis (using the PATH software package) were performed. Analysis of variance showed that most of the studied traits were significantly affected by experimental factors. Based on stepwise regression, the biological yield, harvest index and sepal yield per plant were entered into the regression model in the last step (coefficient of determination = 96.8%). Path analysis showed that biological yield had the largest direct and positive impact on sepal production. Harvest index had a positive direct and negative indirect effect (through its negative relationship with sepals yield per plant and biological yield) on sepal yield per hectare. Finally, sepal yield per plant had a small, negligible positive direct effect, but its indirect effect (through the reduction of harvest index and increasing biological yield) was quite large on sepals yield per hectare. Therefore, biological yield and sepal yield per plant, can be used as indicators for selection for yield in roselle.

1. Introduction

Roselle (*Hibiscus sabdariffa* L.) is an annual industrial and medicinal herb, grows mainly in tropical and sub-tropical areas. This crop probably originated from West Africa or India but is currently grown in many regions of the world, such as parts of Asia, Central America and Australia (Babatunde and Mofoke, 2006; Futuless et al., 2010; Rahbarian et al., 2011; Sonar et al., 2013). In Iran, roselle is mainly produced in Sistan and Balouchestan province on about 300 ha with a mean dry calyx yield of 700–900 kg ha^{-1}. Roselle is cultivated for its stem fibers, leaves, seeds and especially for its edible calyces with the aim of preparing refreshing beverages, jellies and as a natural coloring agent (Fasoyiro et al., 2005a; Futuless et al., 2010; Sonar et al., 2013; Satyanarayana et al., 2015).

Roselle fruits (calyx) are containing many essential nutrients such as vitamin A, vitamin C, minerals, polysaccharide, pectin, β-carotene, anthocyanin and dietary fiber, also contains alkaloids, ascorbic acid, anisaldehyde, β-sitosterol, citric-acid, cyanidin-3-rutinoside, delphinidin, galactose, gossypetin, hibiscetin, mucopolysaccharide, protocatechuic acid, quercetin, stearic acid and wax (Fasoyiro et al., 2005b; Hirunpanich et al., 2005). The approach of roselle is equally significant in alternative system of medicine as well as in conventional system of medicine. It is known to have anti-scorbutic, anti-diabetic and anti-hypertensive effects and so is emollient, diuretic, refrigerant, and sedative. The plant products (*viz.*, calyx, leaves, oil extracted from seeds) is also reported to be antiseptic, aphrodisiac, astringent, cholagogue, demulcent, digestive, purgative and resolving. In addition, it is used as a folk remedy in the treatment of abscesses, bilious conditions, cancer, cough, debility, dyspepsia, fever, hangover, heart ailments, hypertension, and neurosis (Hirunpanich et al., 2005; Da-Costa-Rocha et al., 2014).

The relationship between traits with yield is important, but to calculate the correlation coefficients did not specify the nature of the characteristics and uses of path analysis allowed the identification of direct and indirect effects of traits there. For this purpose, plant breeders are used path analysis as a tool to determine the effective traits in

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Table 1
The main climatic indices of experimental site during experiment.

Growth month	Precipitation (mm)	Potential evaporation (mm)*	Monthly average humidity (%)	Monthly sunshine (h)	Average of minimum temperatures (°C)	Average of maximum temperatures (°C)
April	12	135.8	38	248.5	11.7	25.1
May	5.3	297.2	26	287.6	17.1	30.8
June	0	417.6	16	344.1	21.1	35.8
July	0	479.0	16	355.6	24.2	37.5
August	0	418.9	16	368.1	21.5	35.5
September	0	304.3	22	343.9	16.8	32.2
October	1.9	216.1	27	288.4	14.4	29.0
November	9	97.7	45	206.8	8.3	20.2

These data were used for determination of irrigation dates in treatments of normal (irrigation after 100 mm pan evaporation) and deficit irrigation (irrigation after 200 mm pan evaporation). The amount of used water in each irrigation time was 600 m^3 ha^{-1}.

yield. Path analysis has been proposed by Wright (1921), a method in which the relationship between the characters and their direct and indirect effects is clarified. Path analysis is a method that reveals the relationships between traits and their direct and indirect effects on performance. This method requires the identification of casual relationships among traits (Allah-Gholipour, 1997). The simple correlation coefficient, does not provide an accurate opinion of the importance of direct and indirect effects of each yield components (Rafeie and Saeidi, 2005). Moreover, since the number of traits that have a negative correlation with respect to complex traits together, final judgment cannot be made solely on the basis of simple correlation coefficients (Tousi-Mojarad and Bihamta, 2007). Also, often a trait, in addition to direct effects on some traits, have an effect on these indirectly via other traits. In this case, path analysis (particularly sequential path coefficients analysis) method determine the share of direct and indirect effects on other traits (Rezaei and Soltani, 1998; Rafeie and Saeidi, 2005).

Environmental conditions and genotype interaction affected the relationships among plant characters. Correlation and path analysis are the two best approaches to determine these relations (Dalkani et al., 2011) that has been used by many researchers in different crops including many medicinal plants (Chitra and Rajamani, 2010; Karuppaiah and Senthil Kumar, 2010; Bardideh et al., 2013). So far, in some studies the path and factor analysis and genetic improvement of roselle has been investigated (Ibrahim et al., 2013a; Sabiel et al., 2014), but there is a few attentions and limited information regarding its genetics, breeding and production (Sabiel et al., 2014). Therefore, the aim of this study was determine the sepal yield-related characters and their relationships with others for determination of the best criteria for high sepal yield condition for screening, using factor and path analysis and separate the relationship between sepal yield and its components into direct and indirect effects and distinguish the cause and effect relationships between them.

2. Material and methods

For evaluation of the sepal yield-related criteria in roselle and their relationships with others for determination of the best index for high yield condition screening, using factor and path analysis, an experiment was conducted during 2015. Roselle plants were grown as a split–split plot based on a randomized complete block design with three replications, in experimental station of Sarayan Faculty of Agriculture (33° N, 58° E and 1450 msl), University of Birjand, Iran. The experimental site has semi-arid climate with an average annual precipitation and mean annual temperature of 110 mm and 17 °C, respectively. The main climatic indices of experimental site during study are presented in Table 1.

Experimental treatments were contained three factors including irrigation with two levels (normal and deficit irrigation: irrigation after 100 and 200 mm pan evaporation, respectively), humic-acid with two levels (0 and 4 kg ha^{-1}) and mycorrhizal inoculation with three levels (*Glomus versiforme*, *Glomus intraradices* and no-inoculation). Water regime was considered as the main plots, humic acid application levels were sub-plots and mycorrhizal inoculation treatments were sub-sub-plots. There were three replications in experiment with 12 plots per replicate (Each plot had an area of 4 m^2). Mycorrhizal species were achieved from TuranBiotech company (Turanbiotch.ir), which were prepared by trap culture method on berseem clover (*Trifolium alexandrinum* L.). Mycorrhizal fungi according to the manufacturer's recommendation were used under the planted seeds at the rate of 2 g per plant. The used humic acid was from Brand of Humixtract, produced in Spain. Its total humic extract, humic acids, polycarboxilic acid, potassium oxide and calcium oxide were 70, 38, 32, 10 and 1% W/W Total, respectively. Humic acid was used through irrigation water two times during vegetative growth (15 and 35 days after emergence).

Manual seed planting (using ‘Saravan’ cultivar as a local accession) was carried out on 20th April, 2015 with density of 20 plant per m^{-2} (10 × 50 cm intra- and inter-row distances). The main physical and chemical properties of experimental site with respect to soil are shown in Table 2. All plots were irrigated similarly two times during the first week after seed sowing and then irrigation treatments were done separately in all plots belonging two different irrigation regimes until November 15 when irrigation was stopped. The amount of used water in each irrigation time was 600 m^3 ha^{-1}. Irrigation was stopped two weeks before roselle fruits were harvested.

At the end of growth cycle, for measuring of some morphological indices and yield components of roselle, five plants were selected randomly in each plot on 20th November, 2015. The selected plants were cut from above soil and then the amounts of mean plant height, number of lateral branches per plant, number of fruits per plant, mean fresh weight of fruit, leaf area, leaf dry weight, plant dry weight and sepals

Table 2
Main physical and chemical properties of experimental site with respect to soil.

EC† (mS cm^{-1})	pH	O.C. ‡ (%)	N_{total} (%)	P_{ava} (%)	K_{ava} (%)	Sand (%)	Silt (%)	Clay (%)	Soil texture
2.27	8.49	0.13	0.016	0.0002	0.019	48.5	22.5	29	Loam

†EC = electrical conductivity.
‡O.C = organic carbon.