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Effect of Humic Acid on Fruit Yield Attributes, Yield and Leaf Nutrient Accumulation of Apple Trees Under Calcareous Soil

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Abstract

Background/Objectives: The availability of nutrients to plants is one of the main constraints under calcareous soil. This study aimed to investigate the influence of humic acid on nutrients availability and fruit yield of apple trees at district Ziarat using red delicious apple variety of same age. **Methods:** Six rates of humic acid were tested in randomized complete block design (RCBD) with three replications. These rates were included as T1 = Control (0.0 g Humic acid), T2 = 50 g potassium humate tree⁻¹, T3 = 75 g potassium humate tree⁻¹, T4 = 100 g potassium humate tree⁻¹, T5 =125 g potassium humate tree⁻¹ and T6 = 150 g potassium humate tree⁻¹. **Findings:** The results showed that the apple trees received 125 and 150 g potassium humate tree⁻¹ recorded statistically at par but higher fruit set (71.68 and 74.66%) and fruit yield (262.15 and 264.46 kg tree⁻¹) and higher fruit retention (91.63%) with minimum fruit drop (8.37%) at 150 g potassium humate tree⁻¹. However, control treatment resulted in greater fruit drop (72.43%) and minimum fruit set (21.10%). Similarly, the application of 125 and 150 g potassium humate tree⁻¹ manifested higher leaf macro and micro nutrients concentration. There was positive and significant correlation between apple fruit yield and leaf nutrient concentration which evidenced the beneficial and stimulatory effect of humic acid on nutrient availability and yield. **Applications/Improvements:** From this study it is suggested that different sources of humic acid need to be tested on apple so that the best source of humic acid can be found for quality fruit production of apple.

Keywords: Apple Trees, Calcareous Soil, Fruit, Yield, Humic Acid, Leaf Nutrient Concentration

1. Introduction

Production of deciduous fruits in Balochistan has a special advantage over other fruit growing areas, because of its environmental condition. The diversity of climates in the province is a blessing for growing various fruit crops ranging from temperate to sub-tropical and tropical. Among them, apples are the first largest planted fruit in Balochistan and it covers 0.101 million hectares with a production of 0.224 million tones. Apple contributing more than 42 and 23% of total areas and production of the

country's respectively¹. Apple of the province is famous for its special taste and quality. But due to lack of organic matter in soil and imbalance use of chemical fertilizer have resulted in low and poor quality apple fruit production. In addition, Baluchistan is the key contributor of apples in Pakistan with 70% of apple production, followed by KPK contributing 25% of the national apple growth². The major apple growing districts in Baluchistan are Loralai, Mastung, Kalat, Killa saifull, Pishin, Quetta, Ziarat and Zhob with total area of 29900, 29925, 22726, 22121, 57535, 18327, 25066 and 41201 hectares³. Among them,

three districts such as Pishin, Quetta and Ziarat hold a special position with respect to yield and quality of apple production. The commonly grown commercial varieties in these districts include Tor Kulu (Red Delicious), Shin Kulu (Golden Delicious), Amri, Mashadi and Kashmiri. Whereas, Kaja (Katja) is a newly introduced early matured variety showing promising results and area is increasing rapidly⁴ mentioned that Tor Kulu, Shin Kulu, Amri, Mashdi, Kashmiri and Kaja varieties contributed 57, 29, 4, 1.60, 7.68 and 0.72% production respectively in the area. However, Tor Kulu is the most popular apple variety among consumers and the farmer community accounting for about 35% of the apple production in Baluchistan.

Apples are one of the most widely grown tree fruits. Apple trees originated in Central Asia and the first five countries in the apple production are China, the United States, India, Turkey and Poland respectively. Global average apple yields rose from 11 t/ha in 2002 to more than 15 t/ha in 2012. Apples rank third in global fruit production with about 76 million tonnes in 2012⁵ One of the important components of high quality soil is organic matter which directly affects soil physical, chemical and biological properties and its presence in sufficient quantity is indispensable for sustainable crop production and friendly environment⁶. In tropical and sub-tropical areas of the world where high temperature results in high decomposition rate of soil organic matter affecting soil fertility and productivity with low crop growth and yield^{7,8}. In developing countries like Pakistan where inputs are in short supply and removal of crop residues for fuel and feed purpose further enhance the loss of organic matter in soil resulting in low yield. However, the enriched deposits of low rank coal containing humic acid are found in large quantities in Pakistan which can be used as a source of organic matter by extracting its humic acid contents9 because it contain phenolic, acidic, amino and quinine groups which helps in the availability of nutrients in calcareous alkaline soil poor in organic matter. This has aromatic structure and is soluble in alkali because it is surrogated by carboxyl, phenolic, hydroxyl, and alkyl groups which are connected together through either linkage¹⁰. The application of coal-derived sodium humate under calcareous soil increased growth, yield and nutrient uptake of various crops¹¹⁻¹⁶.

One way of plant growth improvement is through the structural improvement of both clay and sandy soil allowing for better root growth development. Plant growth is also improved by the ability of the plant to uptake and receives more nutrients. Humic acid is especially beneficial in freeing up nutrients in the soil so that they are made available to the plant as needed. For instance, if an aluminum molecule is binded with a phosphorus one, humic acid detaches them making the phosphorus available for the plant. Humic acid is also especially important because of its ability to chelate micronutrients increasing their bio-availability. The purpose of the present study is to determine the extent to which humic substances (commercially available) increase nutrient availability and improve overall soil properties that ultimately exert positive effect on apple fruit production and quality. The main objectives of this study are to evaluate the rate of commercially available humic acid on apple production and quality and to find out the beneficial effect of humic acid on the availability of nutrients under calcareous soil.

2. Materials and Methods

This experiment was conducted on fruit bearing apple trees of same age and variety during 2015-16. The orchard was selected at Tehsil Ziarat owned by farmer. The number of trees as per treatments was chosen and tagged properly. The experiment was planned in randomized complete block design with three replications. The different doses of humic acid as commercially available potassium humate were evaluated on apple trees and treatments were set as given bellow:

T1 = Control (0.0 g Humic acid)

T2 = 50 g potassium humate tree⁻¹

 $T3 = 75 \text{ g potassium humate tree}^{-1}$

 $T4 = 100 \text{ g potassium humate tree}^{-1}$

T5 = 125 g potassium humate tree⁻¹ T6 = 150 g potassium humate tree⁻¹

These doses of humic acids were applied after fruit harvest and before flowering i.e. at the end of February, 2016 along with basal dose of recommended N, P and K @ 300-225-225 g tree⁻¹ along with Fe and Zn application. All the orchards production and maintenance practices were carried out as per requirement following standard procedure. However, composite soil samples was collected from the selected orchards before the application of treatments and analyzed for physicochemical properties

and nutrient status. The data were recorded which were

included no. of flowers per tree⁻¹, fruit set (%), fruit drop (%), fruit retention (%), no. of fruits tree⁻¹ after flowering, no. of fruits tree⁻¹ at harvest, fruit yield (kgtree⁻¹) and leaf nutrient concentration (N, P, K, Cu, Fe, Mn and Zn).

2.1 Number of Flowers Tree⁻¹

Number of flowers tree⁻¹ was counted at balloon stage.

2.2 Fruit Set (%)

At balloon stage the total number of flowers was counted then the number of set fruits was counted two weeks after full bloom. Fruit set% was calculated according to the formula:

Fruit set% = number of set fruits / total number of flowers (balloon stage) X 100

2.3 Fruit Drop (%)

Fruit drop was calculated by the following equation:

Fruit drop% = total number of fruit set - total number of fruits at harvest time / total number of fruit set x 100.

2.4 Fruit Retention (%)

Fruit retention was determined by counting the number of fruits at harvest time / initial number of fruit set x 100.

2.5 Number of Fruits Tree⁻¹

Fruits were picked in October and numbers of fruits tree⁻¹ were counted.

2.6 Yield (kg tree⁻¹)

At harvest time, fruits tree⁻¹ for each treatment was weighted and then average yield (kg tree⁻¹) was estimated.

2.7 Soil Analysis

A soil sample with depth of 30 cm was collected from each tree under the canopy. Hydrometer method was used for soil mechanical analysis¹⁷, Soil pH and EC was determined in 1:5 soil and water suspension at 25°C according to the method described by McK eague and McLean¹⁸⁻¹⁹, organic matter by oxidation method^{20,21} and total nitrogen by Kjeldahl method²². AB-DTPA extraction solution was used for extracting P, K, Cu, Fe, Mn and Zn from soil²³. In the clear filtrate of AB-DTPA soil extract, phosphorus was determined on Spectrophotometer at 880 nm wavelength and potassium on Flame Photometer.

2.8 Leaf Analysis

Leaf samples were collected from current-season terminal shoots and selected mid-shoot leaves on the periphery of the apple tree in July. Two to three leaves was taken from an individual terminal shoot and totally 100 leaves as per sample was collected. The samples was then put in the paper envelopes, labeled them with permanent marker and delivered to the Laboratory of Soil and Water Testing of ARI Quetta the same day and stored it over there at 20 °C for next coming working day. The samples was decontaminated and washed following the method of Sonneveld and Dijk²⁴, oven dried at 80 °C, ground to 20 mesh and stored in plastic bags at 4 °C in the Lab. for target analysis.

Weighed 0.3g of the prepared plant sample and wet digested using hot sulfuric acid with repeated additions of 30% hydrogen peroxide (H₂O₂) until the digestion was completed, then this digest was used for the determination of total nitrogen (N), phosphorus (P), potassium (K), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn)²⁴. For phosphorus, pipetted 10 ml of the digest into a 100 ml volumetric flask, added 10 ml ammonium-vanadomolybdate and diluted the solution with Demonized water up to the mark. Then, read the absorbance of the blank, standards, and samples after 30 minutes at 410-nm wavelength on Spectrophotometer. The potassium in the digest was determined directly by Flame Photometer while micronutrients were determined on atomic absorption spectrophotometer. Whereas, total nitrogen was determined by Kjeldhal method²⁵.

2.9 Statistical Analysis

The collected data was subjected to single way analysis of variance through randomized complete block design and significant differences between treatments was determined through LSD test at 5% probability level using computer program SPSS (Sigma Plot, San Rafael, CA).

3. Result and Discussion

The pre-soil analysis of the experimental apple orchard revealed that soil was sandy clay loam in texture with particle distribution of sand, silt and clay particles of 54.7, 23.2 and 22%. Further, soil was calcareous, alkaline in nature (pH 8.10) and non-saline (EC_e 1.22 dSm⁻¹) with low organic matter contents (0.81%). The soil nutrient status of study area as shown in Table 1 manifested that Soil total nitrogen, AB-DTPA extractable P (2.43 mg kg⁻¹)

and Zn (0.87 mg kg $^{-1}$) were low while AB-DTPA extracble soil K (142 mg kg $^{-1}$), Cu (0.62 mg kg $^{-1}$) and Mn (3.21 mg kg $^{-1}$) were high but AB-DTPA extractable Fe (3.38 mg kg $^{-1}$) was in medium range.

Table 1. Pre soil analysis of the experimental site (apple orchard) at Ziarat

Soil characteristics	Units	Value	
Sand	(%)	54.7	
Silt	(%)	23.3	
Clay	(%)	22.0	
Textural Class		Sandy clay loam	
рН		8.10	
EC	(dSm ⁻¹⁾	1.22	
O.M.	(%)	0.81	
Total Nitrogen	(%)	0.062	
AB-DTPA extractable P	mg kg ⁻¹	2.43	
AB-DTPA extractable K	mg kg ⁻¹	142	
AB-DTPA extractable Cu	mg kg ⁻¹	0.62 high	
AB-DTPA extractable Fe	mg kg ⁻¹	3.38 medium	
AB-DTPA extractable Mn	mg kg ⁻¹	3.21 high	
AB-DTPA extractable Zn	mg kg ⁻¹	0.87 low	

The number of flowers tree⁻¹, no. of fruits tree⁻¹ after flowering, no. of fruits tree⁻¹ at harvest, fruit set (%), fruit

drop (%), fruit retentions (%) and fruit yield (kg tree⁻¹) as affected by humic acid application is given in Table 2. The overall mean of flowers tree⁻¹ was ranged from 997 to 2618 with mean value of 1870, fruits tree⁻¹ after flowering was 793.9 to 2048 with mean value of 1388.8, fruits tree⁻¹ at harvest was 207.4 to 1985 with mean value of 1083.7, fruit set was 20.8 to 75.8% with mean value of 54.2%, fruit drop was 3.0 to 73.9% with mean value of 27.3%, fruit retention was 26.1 to 97.0% with mean value of 72.7% and yield was 39.3 to 295.9 kg tree⁻¹ with mean value of 171.9 kg tree⁻¹ respectively.

The statistical analysis regarding the effect of humic acid on fruit yield and its attributes of apple trees as given in Table 2 exhibited highly significant (p \leq 0.05) differences. The maximum number of flowers tree $^{-1}$ (2266.7), no. of fruits tree $^{-1}$ after flowering (1841.2) and no. of fruits tree $^{-1}$ at harvest (1606.0) were obtained when 150 g potassium humate tree $^{-1}$ was applied immediately followed by 125 g potassium humate tree $^{-1}$ that were statistically at par from each other. While minimum of these parameters were recorded in control trees where no humic acid was applied. However, at 50 and 75 g potassium humate rates, both no. of flowers tree $^{-1}$ and no. of fruits tree $^{-1}$ after flowering showed statistically at par values. Furthermore, greater fruit set (74.66%), fruit retention (91.63%) and fruit yield (264.47 kg tree $^{-1}$) were found in treatment

Table 2. Effect of humic acid on fruit set (%), fruit drop (%), fruit retention (%) and fruit yield of apple

Treatments	No. of flowers tree ⁻¹	No. of Fruits tree ⁻¹ after flowering	No. Fruits tree ⁻¹ at harvest	Fruit Set (%)	Fruit drop (%)	Fruit retentions (%)	Fruit yield (kg tree ⁻¹)
Control (0.0g Humic acid)	1199.7d	915.3d	253.3e	21.10c	72.43a	27.57e	46.40e
50g potassium humate tree ⁻¹	1741.3c	1058.0c	663.0d	41.97b	37.61b	62.39d	87.0d
75g potassium humate tree ⁻¹	1788.0c	1110.3c	866.3c	44.54b	22.33c	77.67c	154.66c
100g potassium humate tree ⁻¹	1988.0b	1612.0b	1418.7b	71.24a	12.39d	87.61b	216.53b
125g potassium humate tree ⁻¹	2236.7a	1795.3a	1695.0a	71.68a	10.96d	89.04b	262.15a
150g potassium humate tree ⁻¹	2266.7a	1841.2a	1606.0a	74.66a	8.37e	91.63a	264.47a
CV	3.43	3.64	9.44	7.80	4.99	1.88	7.43
LSD (P < 0.5)	116.62	91.89	186.10	7.68	2.48	2.48	23.22
F value	113.7	195.4	95.9	79.1	971.6	971.6	154.5

Mean bearing the same letters are statistically alike

when 150 g potassium humate tree-1 was applied. statistically, both fruit set and fruit yield tree-1 were at par on both higher rates of humic acid i.e. 125 and 150 g potassium humate tree-1. Whereas, fruit retention showed non-significant differences at 100 and 125g potassium humate tree⁻¹. However, minimum fruit set (21.10%) and yield (46.40 kg tree⁻¹) was observed in control tree. In case of fruit drop, the higher rate of potassium humate (150g tree⁻¹) expressed minimum fruit drop (8.037%) followed by 10.96 and 12.39% at 100 and 125g potassium humate tree-1 which were statistically at par from one another but control trees showed higher fruit drop (72.43%). The improvement in fruit set and fruit retention have resulted in increased fruit yield tree-1. In entire apple growing regions in Balochistan including district Ziarat, fruit drop is one of the serious problems of apple production. The application of humic acid has approved an excellent source of soil conditioner leading to enhance overall soil health and quality. Humates have long been used as a soil conditioner, fertilizer and soil supplement²⁶. The efficiency of applied inorganic fertilizer is quite low due to calcareous nature and alkaline conditions of the soil. The application of humic acid works as a chelating agent for nutrients already present in the soil and make them available to plant. The results obtained through this study is in line with findings of 27 who conducted experiment on pomegranate to study the effect of humic acid and deficit irrigation and their results showed that no. of flowers tree-1, fruit set, fruit retention were increased significantly with increasing rate of humic acid i.e. from 32 g to 48 g tree⁻¹. They also reported reduction in fruit drop percentage on higher humic acid rates. Positive and significant effect of humic acid has also been reported on grapes²⁸ and on Le-Conte pear^{29,30} applied humic acid to lemon trees in soil in combination with chemical fertilizer while³¹ tested both humic acid and fertilizer on apple and³² applied humic acid as biostimulant on Desert Red Peach and Anna Apple trees. The scientific literature has recently demonstrated that humic acid exert directly or indirectly effects on plant growth processes such as morphological, physiological, genetic and biochemical process³³⁻³⁵.

Apple leaf nutrient concentration as affected by humic acid application is given in Table 3. The overall mean leaf nitrogen (N) concentration was ranged from 1.3 to 2.7% with mean value of 2.2%, phosphorus (P) was 0.10 to 0.40% with mean value of 0.30%, potassium was 1.10 to 2.0% with mean value of 1.6%, copper (Cu) was 3.7 to 46.8 mg kg⁻¹ with mean value of 25.0 mg kg⁻¹, iron (Fe) was 35.8 to 202.2 mg kg⁻¹ with mean value of 137.4 mg kg⁻¹, Manganese was 18.5 to 130.3 mg kg⁻¹ with mean value of 95.6 mg kg⁻¹ and zinc (Zn) was 15.7 to 101.5 mg kg⁻¹ with mean value of 58.3 mg kg⁻¹ respectively.

The statistical analysis regarding the effect of humic acid on apple leaf nutrient concentration as given in Table 3 exhibited highly significant ($p \le 0.05$) differences. The maximum leaf N, P and K concentration (2.52, 0.36 and 1.87%) was noted in 150 g potassium humate applied trees followed by 2.52, 0.36 and 1.81% in 125g potassium humate applied trees while minimum N, P and K concentration (1.38, 0.11 and 1.22%) was observed in controlled trees were no potassium humate was applied.

Table 3. Effect of humic acid on leaf nutrient concentration of apple

Treatments	Leaf Macronutrient conc. (%)			Le	Leaf Micronutrient conc. (mg kg ⁻¹)			
	N	P	K	Cu	Fe	Mn	Zn	
Control (0.0 g Humic acid)	1.38f	0.11d	1.22f	4.26e	45.50d	22.01c	17.10f	
50 g potassium humate tree ⁻¹	2.18e	0.25c	1.44e	18.11d	135.78c	102.50b	40.25e	
75 g potassium humate tree-1	2.23d	0.25c	1.66d	25.46c	150.31bc	109.02ab	53.01d	
100 g potassium humate tree ⁻¹	2.45c	0.28b	1.76c	26.41c	160.46ab	110.18ab	64.59c	
125 g potassium humate tree ⁻¹	2.52b	0.36a	1.81b	33.70b	162.99ab	114.64a	80.35b	
150 g potassium humate tree ⁻¹	2.58a	0.36a	1.87a	42.19a	169.54a	115.05a	94.65a	
CV	0.85	1.51	1.14	6.04	6.88	5.67	3.68	
LSD (P <0.5)	0.0345	0.007	0.034	2.75	17.20	9.85	3.91	
F value	1625.1	1531.2	543.8	223.3	72.8	135.0	506.6	

Mean bearing the same letters are statistically alike

At 125 and 150g potassium humate tree⁻¹ produced statistically at par leaf P concentration. Whereas, in case of micronutrient, same pattern of leaf nutrient concentration was examined, higher leaf Cu, Fe, Mn and Zn concentration was found where 150 g potassium humate tree⁻¹ was applied followed by 33.70, 162.99, 114.64 and 80.35 mg kg⁻¹ Cu, Fe, Mn and Zn in 125g potassium humate applied trees. Statistically leaf Fe concentration was at par on 100 and 125g potassium humate applied trees while leaf Mn concentration was at par on 75 and 100g potassium humate as well as 125 and 150 g potassium humate applied trees. But controlled trees manifested minimum concentration of micronutrients. It means that the application of humic acid increased nutrient availability under calcareous soil because leaf nutrient concentration of apple trees under control showed minimum level of macro and micro nutrients. Whereas all rates of potassium humate resulted in higher nutrient accumulation in leaf over control. But the higher rates of potassium humate like 125 and 150 g tree⁻¹ resulted in comparatively maximum leaf nutrient accumulation of apple trees. Because the main function of humic acid in soil is to work as nutrient stimulating agent having various functional groups that hold nutrients and do not let them to be adsorbed on soil matrix and make them available to plants³⁶⁻³⁸. In addition to the application of humic acid increased soil organic matter leading to improved soil structure that indirectly improved all soil physical, chemical, and biological properties. According to³⁹ that commercially available product of humic acid have various plant essential elements that help to enhance soil fertility by controlling nutrient availability and holding them on mineral surfaces which ultimately influence growth and yield of plant³⁹. Other research studies showed that humic substances increased fruit weight and yield of apple and enhanced soluble contents of apple fruit^{32,40}. Additionally, humic have stimulatory influence on growth roots like auxins.²⁷ Likewise, there is growing interest of the use of humic acid and K-humate as a substitute to chemical fertilizers⁴¹.

The correlation between apple fruit yield and leaf micronutrient concentration as shown in Figure 1 is positive and significant. According to coefficient of determination (R^2), fruit yield was positively and significantly associated with leaf Cu concentration ($R^2 = 0.887$), Fe ($R^2 = 0.674$), Mn ($R^2 = 0.593$) and Zn ($R^2 = 0.936$).

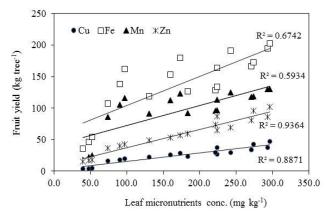


Figure 1. Linear correlation between fruit yield and leaf micronutrient concentration of apple under humic acid application.

4. Conclusion

The availability of nutrients to plants is one of the main constraints under calcareous soil Through this study, the stimulatory effect of humic acid on nutrients availability, fruit set, fruit drop, fruit retention and fruit yield of apple trees were investigated. The evaluated rates of humic acid indicated that 125 and 150g potassium humate tree⁻¹ produced higher fruit set and fruit retention percentage and higher leaf nutrient accumulations leading to improve fruit yield tree-1. There was positive and significant correlation between apple fruit yield and leaf nutrient concentration which evidenced the beneficial and stimulatory effect of humic acid on nutrient availability and yield. From this study it is suggested that different sources of humic acid needed to be tested on various apple varieties so that the best source of humic acid can be found for quality fruit production of apple.

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