

CITRUS NUTRITION ON CALCAREOUS SOILS

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Abstract

Citrus is an important exportable fruit commodity of Pakistan and is a rich source of minerals and vitamin C. Punjab is the main citrus growing province as it contributes more than 95 % citrus production. Sindh and NWFP contribute about 4 %, and Baluchistan contributes only 0.8 % in citrus production. Soils of Pakistan are relatively young and characterized as alkaline and calcareous with low organic matter content. Citrus nutrition management on calcareous soils differs from that on non-calcareous soils because of the effect of soil pH on soil nutrient availability and chemical reactions that affect the loss or fixation of some nutrients. The presence of CaCO₃ directly or indirectly affects the chemistry and availability of nitrogen (N), phosphorus (P), magnesium (Mg), potassium (K), manganese (Mn), zinc (Zn), and iron (Fe).

To avoid ammonia volatilization, ammonium-N containing fertilizers should be incorporated into the soil following irrigation. To increase P use efficiency, fertilizers should be applied on a regular, but not necessarily frequent, basis.

Citrus planted on calcareous soils may require above normal levels of Mg or K fertilizer for satisfactory nutrition. The easiest way to correct Zn and Mn deficiencies of citrus in calcareous soils is through foliar application of inorganic or organically chelated forms. Technologies aiming increased use efficiency of water and fertilizers should be adopted. Recommendations should be based on soil and leaves tissue analysis along with visual symptoms, and should be site specific. In this paper, we will discuss major nutritional problems of citrus grown on calcareous soils and measures to cope with these problems in a sustainable way.

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Introduction

Citrus is one of the most important fruit crops in South East Asia. Citrus cultivars are grown in varying quantities in countries with tropical or sub tropical climate. Citrus stands first in area and production among the world's tree fruits. Citrus fruits are notable for their fragrance, and most are juice-laden. They contain a high proportion of citric acid giving them their characteristic astringent odour and flavour. They are also good sources of vitamin C.

Citrus yields per unit area in Asia are low compared to Western countries, while production and marketing costs are relatively high. The WTO agreement makes it imperative for the citrus industries of Asian countries to become more competitive. This will enable farmers to hold their place in domestic markets in the face of trade liberalization, and if possible to expand it.

Citrus Production in the Country

Citrus trees can be grown on a wide range of soils, including deep sandy loam, loam and clay loam. However, they do not

grow well in very heavy, clayey, sandy, alkaline or water logged soils. Citrus fruits trees are grown in tropical and sub-tropical climate. Temperature affects time of blooming, maturity, production and fruit quality of citrus.

Climate of Pakistan is arid and semi-arid, and soils are relatively young. Mainly six soil orders vis. Aridisols, Alfisols, Entisols, Mollisols, Inceptisols and Vertisols are dominant in the region. Soils are alkaline (pH values > 7) because of the presence of calcium carbonate (CaCO₃), which dominates their behaviour.

Citrus are the most important fruit crops of Pakistan, grown on an area of 197,000 hectares with annual production of 1.9 million tons. The major production areas are widely scattered and had their own soil types and management problems. Punjab is the main citrus growing province in the country contributing above 95 % in citrus production. Cumulative contribution by Sindh and NWFP is about four percent and Baluchistan contributes only 0.8-1 % in citrus production.

Table 1: Major Citrus Growing Areas in Pakistan:

Province	Districts
Punjab	Distt. Sargodha, Sahiwal, Lahore, Sialkot, Jhang, Minwali, Multan, Gujranwala
NWFP	Mardan, Peshawer, Swat, Swabi, Noshera, Hazzara
Sindh	Sukkur, Khairpur, Nawabshah
Baluchistan	Mekran, Sibi and Kech

Source: PARC, webpage

Citrus production in the country is stagnant during last decade inspite of the increasing demand. Disease, particularly greening and virus diseases, low soil fertility, imbalanced fertilization, low fertilizer use efficiency, variable soil salinity, lack of suitable improved

varieties, lack of disease-free planting material are some of major factors contributing towards this stagnant yield of citrus. Out of total cultivated soils, 80 % soils are irrigated. Quantity and quality of irrigation water also hampers fruit production.

Table 2: Area and Production of Citrus in Pakistan

Year	Total Area (Hectares)	Production (Tones)
1994-95	190743	19342777
1995-96	193573	1959464
1996-97	194374	2002563
1997-98	196098	2036963
1998-99	197021	1861468

Source: PARC, Islamabad.

Mineral Nutrition and Citrus Fruit Quality

Citrus fruit quality is normally defined in terms of usual commercial standards such as colour, size, appearance, storage potential, fruit juice content, soluble solids and acid concentrations. Fruit quality is affected by several factors including cultivar, rootstock, climate, soil, pests, irrigation and nutrition.

Mineral nutrients have significant impacts on fruit quality and shelflife during harvest, packing house operations, storage, and distribution. These include effects on fruit color, texture, disease susceptibility, juice composition, and the development of physiological disorders (Table 3 & 4). Role of potassium, calcium and magnesium in influencing representative characteristics of fruit quality, especially texture, sugar and flavour production is well established. Optimum management of nutrients is critical for obtaining maximum yield. Nutrient levels that produce maximum yield may not always correspond to those that result in the highest fruit quality and maximum quality retention. Further, although the addition of nutrients above optimum levels may not reduce yields, it can have either negative or positive effects on aspects of quality that are not readily apparent.

Link (1982) conducted long term experiments to study the effect of varying levels of applied N on fruit quality. He reported that fruit size increased considerably with increasing rates of nitrogen. Cell size in all cultivars used was not influenced either by the rate or the date of nitrogen application. Russetting of the fruits was unaffected by either the rate or time of nitrogen

application. The concentration of titratable acid sometimes was highest in fruit from low nitrogen plots. Moreover, decomposition of the acids seemed to progress more slowly in low nitrogen than in high nitrogen fruit. Soluble solids were not affected by nitrogen supply. There was a close negative relationship between colour and flavour. Thus the higher rates of nitrogen were reflected in the poorer flavour of the fruits. Nitrogen application to citrus increases incidence of creasing and scab but decreases incidence of peel blemishes like wind scar, mite russetting, and rind plugging (Kekri, et al., 2003). Trees grown where plant available N is limited may appear nearly normal but are undersized. Such trees carry little or no fruit load, and can be highly erratic in bearing habit. The color of the fruit peel tends to be pale and smooth, and the juice has lower soluble solids and acid concentrations. In phosphorus (P) deficiency leaves shed prematurely and fruit can drop before normal harvesting time. The fruit of tree deficient in P, will be coarse and rough in texture. The fruit have high acidity in proportion to total soluble solids, delaying fruit maturity (Zekri et al., 2003).

Potassium (K) deficiency in citrus can check or drop rate of photosynthesis. This can lead to reduced production of carbohydrates, reduce fruiting, and increase fruit creasing, plugging and drop. In case of iron deficiency, the leaves are reduced in size, fragile, very thin, and they can shed early. The tree die back severely on the periphery and especially at the top. Manganese deficiency may greatly reduce crop volume and the fruit color. The fruit may become smaller and softer than normal and the rind pale in color (Zekri and Obreza, 2003).

Table 2. Effects of mineral nutrition on fruit quality ("+" = increase, "-" = decrease, "?" = unknown, and "O" = no change)

Parameters	N	P	K	Mg
External Fruit Quality				
Fruit Size	-	0	+	+
Fruit Weight	-	0	+	+
Green fruit	+	+	+	0
Peel thickness	+	-	+	-
Juice Quality				
Juice content	+	0	-	0
Soluble solids (SS)	+	0	-	+
Acid (A)	+	-	+	0
SS:acid ratio	-	+	-	+
Juice color	+	0	-	?
Solids/box	+	0	-	+
Solids/acre	+	+	+	+

Adapted from Zekri et al., 2003.

Table 3: Effects of mineral nutrition on post-harvest diseases ("+" = increase, "-" = decrease, and "O" = no change)

	Stem-end rot	Green mold	Sour rot
N	-	-	0
P	0	0	0
K	-	0	0

Adapted from Koo, 1988.

NUTRITION MANAGEMENT ON CALCAREOUS SOILS

Calcareous soils cover more than 30% of the earth surface, and their CaCO₃ content varies from a few percent to 95% (Marschner, 1995). Calcareous soils occur naturally in arid and semi-arid regions because of relatively little leaching (Brady and Weil, 1999). Calcareous soils have free calcium carbonate (CaCO₃) in the profile. The carbonates, due to their relatively high solubility, reactivity and alkaline character, buffer the pH of most calcareous soils within the range of 7.5 to 8.5. These soils generally have 100%

base saturation, and the exchange complex is dominated by calcium (Loeppert and Suarez, 1996).

Mineral nutrition management on calcareous soils differs from that on non-calcareous soils. Soil reaction (pH) effects mineral solubility, availability and different chemical reactions involving these nutrients. The CaCO₃ contents directly or indirectly affects the availability of certain macro and micro-nutrients in the soil (Pearce *et al.*, 1999; Rahmatullah *et al.*, 1994; Rashid and Rayan, 2004; Ahmad *et al.*, 1992; Zia *et al.*, 1992; Marschner, 1995; Obreza *et al.*, 1993; Brady and Weil, 1999).

Surface area, particle size distribution and reactivity of soil carbonates influence soil chemical and rhizosphere processes (Loeppert and Suarez, 1996). Calcium carbonate provides a reactive surface for adsorption and precipitation reactions, for example, of phosphate, trace metals and organic acids (Talibudeen and Arambarri, 1964; Amer *et al.*, 1985). Rate of volatilization of ammonia is strongly influenced by reactivity of carbonates (Ryan *et al.*, 1981).

Nitrogen Management

Rates of N transformations are strongly affected by alkaline pH values of calcareous soils. Volatilization of

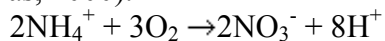
ammoniacal-N fertilizer is significant only in soils with pH values more than 7. Nitrogen loss through ammonia volatilization on calcareous soils is a concern when ammoniacal N is applied to the grove floor without incorporating into the soil. Ammonia loss can also occur in the vicinity of hydrolyzing urea applied on the surface of high pH soils. Ammonium carbonate is produced upon urea hydrolysis, which dissociates to form NH_4^+ , OH^- and CO_2 . In alkaline conditions, NH_4^+ forms NH_3 that may be lost by volatilization (Finck, 1982; Mortvedt *et al.*, 1999).

Table 5: Cumulative NH_3 volatilization (% of N applied) from soil columns in a controlled environment 8 days after application of urea, ammonium sulfate and ammonium nitrate to the surface of five soils.

Soil	Soil properties			Urea		Ammonium sulfate		Ammonium nitrate	
	pH	CaCO ₃	CEC	NH ₃ -N loss	pH after	NH ₃ -N loss	pH after 24	NH ₃ -N loss	pH after 24
		%	(mmol 100g ⁻¹)	(% N applied)	24 hs.	(% N applied)	hs.	(% N applied)	hs.
1	3.7	0.0	19.4	<1	4.0	<1	3.7	<1	3.5
2	5.5	0.0	12.8	24	7.5	1	5.8	<1	5.5
3	6.1	0.6	7.4	38	7.9	4	6.1	<1	5.9
4	7.1	1.8	15.6	27	8.0	32	7.8	9	7.5
5	7.4	75	11.6	43	8.2	49	7.7	8	7.4

Source: Wieszler, 1998

Nitrification is most rapid in soils with pH values between 7 and 8 (Obreza *et al.*, 1982). Ammonium-N fertilizers applied to calcareous soils are converted within a few days to nitrate. The acidity produced during nitrification is quickly neutralized in highly calcareous soils (Imas, 2000).



Ammonium fertilizers are superior as compared to nitrate fertilizers in very

slightly alkaline soils (pH 7-7.5) due to its side effect as a soil acidifier. However, in soils with an alkaline pH and high carbonate content, the excess CaCO₃ provides such a large buffer capacity that the H⁺ ions produced do not alter the soil pH to any appreciable extent (Hagin and Tucker, 1982).

Regardless of the initial form applied, essentially all N fertilizers ultimately exist as nitrate because

nitrification proceeds uninhibited in calcareous soils. Rather than attempt to slow this process, citrus grove management practices should emphasize irrigation and fertilizer application scheduling strategies that increases N use efficiencies in groves. Applying a portion of the required N fertilizer with irrigation water (i.e., through fertigation) and scheduling irrigations to maintain the N in the root zone is a sound method to prevent large N losses.

Management of N fertilizer also should aim to minimize ammonia volatilization. The ammonical-N fertilizer should be moved into the soil profile with irrigation water if rainfall is not likely. Fertigation using either of these N sources is a suitable application method, provided that there is ample time to flush the fertilizer out of the lines and into the soil.

Phosphorus Management

Phosphorus (P) availability is limited on calcareous soils around the globe (Vance et al., 2003) hampering most of the crop yield. At higher pH values, phosphate anions react with Ca and Mg to form phosphate compounds of limited solubility (Rahmatullah, 1994; Mortvedt *et al.*, 1999; Vance et al., 2003). Use efficiency of phosphatic fertilizers on calcareous soils is notoriously low (25 %). After application, P fertilizer undergoes a series of chemical reactions with soil constituents such as adsorption on clay minerals and CaCO₃ surfaces and precipitation with Ca. Consequently, P availability to plants is controlled by the application rate of soluble P and the dissolution and desorption of fixed P (Talibudeen, 1981).

Soluble P fertilizers (triple superphosphate, ammonium phosphates) are the preferred source in calcareous

soils. Strategies regarding P placement and timing, to insure sufficient quantities of soil solution P at points of greatest root activity and at times of peak plant requirement, are of great significance in this regard. Phosphatic fertilizers should be placed in bands to minimize contact between fertilizer and soil (Fuehring, 1973; Hagin and Tucker, 1982).

To maintain P availability to citrus on calcareous soils, water-soluble P fertilizer should be applied on a regular, but not necessarily frequent, basis. Phosphorus fertilizer should be applied each year in newly planted groves, at a rate based on the recommended rate for young trees, until the groves begin to bear fruit. As the trees approach maturity, P applications can be limited to once every few years (Obreza *et al.*, 1993).

Diagnostic information from leaf and soil testing can help to determine whether P fertilization is necessary. The major methods used by soil testing laboratories to measure soil P include Mehlich 1 (double acid), Bray P1, Bray P2 and Olsen (sodium bicarbonate). The Olsen method has been consistently correlated to P uptake by plants growing on calcareous soils, giving particularly good results in the alkaline pH range. Therefore, this method is widely used to predict both deficiency levels and levels of adequacy or possible excess (Fuehring, 1973; Talibudeen, 1981). Leaf tissue testing can be used to determine whether soil P is available to citrus trees. For best results, the leaf P concentration of 4- to 6-month-old spring flush leaves from mature trees should be evaluated. The optimum range for leaf P in mature citrus leaves is from 0.12% to 0.16% on a dry weight basis.

Potassium and Magnesium Management

Available potassium (K) and magnesium (Mg) are usually adequate supply in calcareous soils due to native high levels of exchangeable K and Mg, which are hardly leached in low rainfall regions (Brady and Weil, 1999).

However, an imbalance between plant available Mg, Ca and K ions may lead to Mg and/or K deficiencies to crops. In calcareous soils, the proportion of Ca to other exchangeable cations generally exceeds 80%, and a low proportion of exchangeable Mg (less than 4%) may lead to Mg deficiency in plants (Hagin and Tucker, 1982). High Ca levels in soils suppress Mg and K uptake by crops in part, presumably, through the competition between Ca, Mg and K (Marschner, 1995). Although in calcareous soils of semi-arid and arid regions K levels are generally quite high, K deficiencies have been identified on eroded soils and extremely sandy soils, especially those that have been heavily cropped (Hagin and Tucker, 1982).

If a low concentration of leaf K or Mg is found in a grove that produces satisfactory yield and quality, attempts to increase leaf levels with fertilizer are not necessary. However, if a detrimental condition such as low yield, small fruit, or creasing is observed, an attempt to raise the leaf K or Mg concentration with fertilizer is justified.

Iron Management

Visible Fe deficiency, or Fe chlorosis, is common in citrus grown on calcareous soils because of low plant available Fe, although total iron (Fe) contents of calcareous soils may have adequate levels. Leaf iron concentration is not necessarily related to degree of chlorosis. In chlorotic plants Fe

concentrations can be higher than, equal to, or lower than those in normal plants. Thus, this disorder is not always attributable to Fe deficiency; it may be a condition known as lime-induced Fe chlorosis. Bicarbonate (HCO_3) ions in calcareous soils are factor affecting Fe uptake and/or translocation in the plant. The result is Fe inactivation or immobilization in plant tissue (Romheld, 1997).

Susceptibility to Fe chlorosis depends on plant's response to Fe deficiency stress, which is controlled genetically. Citrus rootstocks vary widely in their ability to overcome low Fe stress (Obreza et al., 1993). More practical way to avoid lime-induced Fe chlorosis is to use tolerant varieties and rootstocks.

Remedy of iron chlorosis in susceptible varieties grown on calcareous soils is very difficult. Inorganic sources of Fe such as ferrous sulfate or ferric sulfate have a very limited effect unless applied very frequently at extremely high rates. Different strategies based on improved management of nutrition can be considered for amelioration of Fe chlorosis. Iron chlorosis can be corrected through soil application of Fe chelates. Commercial chelates are synthetic organic compounds that contain Fe in a complex form and protect it from reacting in soil to form insoluble precipitates. Plants can take up the soluble chelates as complete molecules and then metabolize the metal (Finck, 1982). The most common synthetic chelated forms of Fe include Fe-EDTA, Fe-HEDTA, Fe-DTPA. Application of organic manure and sewage sludge can help to correct Fe chlorosis on plants (Mengel and Kirkby, 1987).

Foliar application of FeSO_4 or Fe chelates has not proven satisfactory on citrus trees because of poor translocation within the leaf. The use of foliar sprays also increases the possibility of fruit and/or leaf burn. For these reasons, foliar application of Fe is not recommended to correct Fe chlorosis of citrus (Obreza et al., 1993).

Zinc and Manganese Management

Soil pH is the most important factor regulating Zn and Mn supply in alkaline soils. Both of Zn and Mn concentrations in soil solution decrease 100 fold for each unit increase in pH (Lindsay, 1972). At alkaline (high) pH values, Zn and Mn form compounds of low water solubility, markedly decreasing their availability to plants. The soil around a plant root (the rhizosphere) tends to be acidic due to root exudation of H^+ ions (Marchner, 1995). Therefore, soils that are slightly alkaline may not necessarily be deficient in Zn or Mn. On highly alkaline soils, however, Zn and Mn deficiencies are not uncommon. Soil applications of Zn and Mn fertilizers are generally ineffective in these situations, but deficiencies can be corrected through the use of foliar sprays. The most common inorganic Zn and Mn fertilizers are the sulfates (ZnSO_4 , MnSO_4) and the oxides (ZnO , MnO). Broadcast application of these compounds to correct Zn or Mn deficiencies in calcareous soils is not recommended due to low use efficiencies. The least expensive way to apply Zn and Mn to citrus is through foliar sprays.

Copper, Boron and Molybdenum Management

Copper solubility is pH dependent and it decreases with increase in pH. In orchards, the Cu requirement is normally

satisfied through foliar sprays of Cu fungicides (Obreza et al., 1993).

Soil pH affects B availability more by sorption reactions than by formation of less soluble compounds. Availability of B is highest in the pH range of 5.5-7.5. Boron is sorbed to Fe and Al oxides in soils and is lowest in the pH range of 6-9 (Mortvedt et al., 1999). There is also an interaction between B availability and the presence of Ca ions. High levels of Ca at high pH reduce the uptake of B. This may explain the fact that high B levels in calcareous soils, considered as toxic in other conditions, do not produce B toxicity in crops (Lucas and Knezek, 1972).

Molybdenum deficiencies are not known in calcareous soil, as Mo availability increases with pH (Lindsay, 1972).

Soil amendments

Soil acidulents (sulfur, sulfuric acid) can improve nutrient availability in calcareous soils by decreasing soil pH. The rates of soil amendments required to cause a plant response depend on the amount of CaCO_3 in the soil. Because plant response to broadcast application of an acidulent is unlikely in this instance, such applications are not recommended. In contrast, soils containing little CaCO_3 , or those that have become alkaline from irrigation water with high levels of bicarbonate, require less acidulation and respond faster. It is feasible to acidify in this situation. Wide variability in soil types precludes a standard recommendation for acidification. If soil acidulents are used, a comprehensive program of soil pH measurement should be undertaken. Portable soil pH meters that can be taken into the field are readily available. Soil pH should be measured prior to, and

periodically after, application of an acidulent to monitor its effect. Decisions regarding the rate and frequency of

subsequent applications of acidulent can be based on desired changes in soil pH and visible plant response.

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