Pakistan Citrus Growers' Handbook: Nutrition of Citrus

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Table of contents

Contents

Contents

1. Introduction

In Pakistan, Citrus trees usually **flower** from late February to early April in most areas where they are grown. The **fruit set** period is reported to be during the months of April and May, with the very important stages of **fruit growth** of fruit **cell division** and fruit **cell expansion** taking place from mid March to just before **harvest**, which occurs in sweet oranges from November to February, and for 'Kinnow' mandarins, from December to March. This is summarised in Figure 1 below

Figure 1: ***Citrus phenology in Pakistan, showing times of rains, various stages of the crop cycle and harvest periods for 'Kinnow' mandarins and sweet orange*****.**

Event	Months of the year											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monsoon	↔									↔	↔	↔
2nd rains		↔	↔									
Budbreak[1]	↔											↔
Flowering		↔	↔	↔								
Fruit set				↔	↔							
Fruit growth					↔	↔	↔	↔	↔	↔		
Growth flush			↔					↔				
Harvest												
Kinnow	↔	↔	↔									↔
Oranges	↔	↔									↔	↔

1: assumed date

In order to be profitable, growers must reap good yields from the trees. Yield of citrus fruit is made up of three factors:
i. The **number of fruits** per tree (affected by fruit set)
ii. The **size and weight** of the fruits at harvest (affected by the number [cell division] and size [cell expansion] of cells in the fruit)
iii. The **number of trees** per hectare

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2. Principles and practices of citrus nutrition.

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2.2. Soil fertility for citrus producers

Good, fertile soil does more than sustain life: soil should itself be alive. Soil has three main components: **physical, chemical and biological**. Each of these is linked to the others, so a change in any one component will lead to changes in the other two.
Good citrus soil has the following characteristics:

- Favourable **physical structure**
- Favourable **air/water balance** (the art of irrigation is to manage soils so that both air and water exist in balance in the soil profile at the same time). prolonged presence of water in the soil profile leads to conditions with low soil oxygen, and make roots more susceptible to attack by nematodes and root rot diseases such as Phytophthora.
- **Correct balance of nutrients**, including organic matter
- **Little physical barrier to root penetration**: roots do not like layered soils and will seldom cross the lines between different soil textures. Also, roots cannot easily penetrate hard or tough soils, with soil toughness being related to soil water and clay content and also to ploughing, where frequent ploughing leads to loss of soil structure and hence to increased soil toughness.

So what would an **ideal citrus soil** be like?

- ✓ 50 –60 cm rooting depth
- ✓ 0.8 to 1.8 mPa soil strength as measured with a soil penetrometer
- ✓ 1.2 to 1.6 t/cubic metre bulk density
- ✓ No sharp transition between soil layers
- ✓ Unrestricted drainage in the top 100 cm of the soil
- ✓ pH (measured in water) between 6.5 and 7.0
- ✓ Sufficient nutrients with no salinity in the top 50 cm.

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2.3. Soil erosion: a direct threat to the livelihood of the grower and the nation.

The aim is to intercept the maximum amount of storm water and channel it into the soil, without adverse effects on the citrus trees. Three methods are usually practiced in Pakistan.

1. Eye brow terraces: Also, called “half-moon terraces”, these are semi circular bunds formed against the slope of the land that catch rainwater for the trees and prevent runoff and loss of soil.

2. Stop wash barriers: These consist of vegetative barriers installed in catchments and usually consist of branches of native trees placed in barriers, followed by use of

live material such as “Mott” grass. The aim of these barriers is to decrease energy of water that is running off the land, and so reduce gully erosion.

3. Surface mulches: As the result of 1 and 2 above, there is usually more grass and weeds that grows in the soil between the trees. This material can be cut and used as mulch in the tree basins. This mulch helps preserve soil stability and structure by reducing raindrop impact on soil and also reduces the evaporation of water from the soil surface when conditions are dry.

The important thing to realise is this: **look after your soil and it will look after you**!

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2.4. Farm nutrients savings plan:

Commercial reality is that the costs of both synthetic fertilisers and the cost of transporting these materials onto farms are both expected to increase up to ten-fold in only the next twenty years; perhaps even sooner.

there is merit in the idea of developing a national farm nutrients savings plan that is based on the following principles for the capturing and recycling of nutrients **on** farms or at least in areas not far removed from agricultural land:

- Development of the recommended practice of on-farm recycling all animal manures, crop residues, weeds, waste food etc as sources of carbon and other nutrients for soil improvement
- On-farm use of perennial crops, deep rooted crops and strip farming to improve soil structure and biological function, and to intercept and recycle nutrients into food or forms of stable carbon such as charcoal.
- Improved watercourse and catchment management to minimise soil erosion through surfacer runoff.
- Use of deep-rooted pastures to reduce loss of nutrients through leaching
- Better irrigation management

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2.5. Soil organic matter: the difference between “living” and “dead” soils? :

Soil organic matter is a source of carbon for the soil as well as the microbes that live in it and the roots that grow there. There are four basic forms of soil organic matter, amounts of which vary greatly in agricultural soils:

i. **Crop or animal residues**, for example pieces of shoots, roots, wood, manure with particles larger than 2 mm size, resting on-or in the soil
ii. **Particulate organic matter**: individual pieces of plant or animal debris smaller than 2 mm diameter but larger than 0.05 mm.
iii. **Humus**: complex carbon rich decomposed materials of particle size smaller than 0.05 mm.
iv. **Recalcitrant organic matter**: mostly pieces of charcoal which break down **very** slowly to release reactive carbon into the soil.

Soil organic matter is a key indicator of soil health, because of its capacity to influence **all** properties of soil, physical, chemical and biological. Soil health is also indicated by soil *resilience*: the ability of soil to return to its initial sate after a disturbance. Soil resilience is also strongly influenced by its organic matter content.

So what are the **benefits of soil organic matter**?

- Improvement and maintenance of soil aggregation and structural stability
- Decreased soil toughness or strength, making root penetration easier
- Increased water holding capacity (so, do **not** increase soil organic matter with soils that are water-logged!)
- Increased soil cation exchange capacity
- Longer nutrient cycling
- Increased soil pH buffering capacity
- Decreased availability of certain soil contaminants, such as certain heavy metals, through a process of sequestration.

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2.6. Basics of citrus nutrition:

In determining how much fertiliser needs to be applied we generally accept that we need to replace at least the quantity of nutrients contained in the fruit taken off the trees. So, how much nutrient does a tonne of fruit take off the trees? This depends on many factors, including the cultivar in question, but is shown in **table 3**, below:

Table 3: *Nutrient removal rates (in kg or grammes of element removed per tonne of fruit harvested) for several citrus varieties.*

Variety	Nutrients removed per tonne of fruit in kg or g per tonne									
	N*	**P**	**K**	**Ca**	**Mg**	Cu**	Fe	Mn	Zn	B
Orange	1.8	0.2	1.9	0.72	0.22	0.6	0.3	0.8	1.4	2.8
Mandarin	1.83	0.16	2.05	0.5	0.11	0.6	2.6	0.4	0.8	1.3
Lemon/lime/grapefruit	1.64	0.16	1.73	0.47	0.13	0.3	2.1	0.4	0.7	0.5

*Quantities of N, P, K, Ca and Mg are in kilogrammes of pure element removed per tonne of fruit
** Quantities of Cu, Fe, Mn, Zn and B are in grammes pure element, removed per tonne of fruit tonne

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2.7. Refining and improving nutrition programmes: leaf and soil analysis

Nutrient deficiency, excess or the resulting imbalance causes poor tree growth, low yield and/or fruit quality, and increased susceptibility of such trees to pest and disease attack. Growers should use any opportunity to make use of leaf and soil analyses to routinely diagnose nutritional problems **before** these become serious

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2.8. Nutrition programmes for citrus trees in Pakistan:

Programmes need to be derived for young, non-bearing trees and for trees in commercial production, since the aim is to promote vegetative growth of non-bearing trees but to support a balance between growth and fruiting in bearing trees. However, one needs to be cautious of the effects of stimulating young trees to grow with extreme vigour, usually by the inclusion of high amounts of nitrate nitrogen in fertiliser programmes, since as already stated, an apparent link exists between how we feed our trees and their susceptibility to pest and disease outbreak.

2.8.1. Pre-plant practices:

Many soil limitations are best addressed by pre-plant operations.
:

- **Confirm suitability of soil for citrus planting**. Do not plant on unsuitable soil
- **Prepare soils for planting**. This often involves ploughing and deep ripping to loosen heavy soils, or to attempt to break up soil layers.
- In areas with shallow soils and high water tables, the option exists to plant trees on **berms or ridges** in order to increase the effective rooting depth. These are usually about 500 to 600 mm tall and approximately 3 metres wide. They are made by soil being scraped up and piled in a windrow of the correct height and width to allow trees to be planted on top of a ridge with newly increased soil and hence rooting depth.

- **Apply soil amendments**:

    - Planting a **cover crop or green manure crop** a year or two before planting is an excellent idea. The crop can be ploughed into the soil the season before planting and will add valuable organic matter to the soil,
    - IWhere soil pH is high and where soil salinity is an issue, gypsum is usually of considerable benefit, since it will not affect soil pH, but helps the salinity issue and provides a source of available calcium. Where soil magnesium levels are low, dolomitic lime can be used.
    - If **phosphorus** is required, the required amount can be applied to the soil and mixed in, since phosphorus moves quite slowly down the soil profile. P can be applied in strips of up to 3 m wide, following the line of the future planting. It can also be applied in the planting hole at a rate of say 800 to 1000g Superphosphate (10, 5% P) per 600 x 600 x 600 mm planting hole. Mix this P in well with the soil, and leave it for 2 to 3 weeks before the new tree is planted. NEVER allow new roots

of citrus trees to come into contact with freshly applied phosphate: it will burn them and the young tree will suffer harm! If soils are to be ridged as above, apply phosphorus before ridging and only to the soil that will form the ridge.

- Growers can apply about 1 kg of well composted manure to each new tree, by putting the manure into the planting hole, and covering it with about 15 cm depth of soil, before planting the new tree.

2.8.2. Fertilisation of non-bearing citrus trees:

The aim is to allow the tree to establish a strong and leafy framework of vegetative growth in the first 3 to 4 years of its life. Generally, fertiliser programmes for young trees concentrate on nitrogen applications, where the steps have been followed outlined in 2.8.1. **With non-bearing, one to four year old trees**, the following steps can be followed:

- Apply 2 kg manure per tree, scattered over the soil surface in radius around the tree but not in contact with the tree trunk. Apply in winter or early spring.
- Make several applications of **nitrogen** at 4 to 6 week intervals if possible, using as a guideline rates shown in table 7 below for various N fertilisers:

Table 7: *Suggested quantities of three nitrogenous fertilisers to be applied annually to citrus trees aged one to four years.*

Tree age (years)	**Fertiliser per tree (grams applied per year)**		
	Urea	Limestone ammonium nitrate	Ammonium sulphate
1	210	350	450
2	420	700	900
3	630	1150	1350
4	840	1500	2000

- The rates of N followed should be about 55 to 60 g of actual N per year of tree age, split if possible into frequent light dressings through most of the growing season. In practice this may involve 4 to 6 applications, made in February to August, timed wherever possible to rainfall to allow fertiliser to enter the soil.
- Broadcast N fertiliser to cover the soil within the irrigation basin, or with micro-sprinklers, to cover the soil extending to about 500 mm beyond the furthest extent of the leaf canopy of the tree.
- For soils confirmed by soil analysis as low in potassium and /or phosphorus, consider applying the following quantities of fertiliser:

Table 8*: Suggested quantities of three commonly used potassium, sulphur and phosphorus fertilisers to be applied annually to citrus trees aged one to four years*

Tree age (years)	**Fertiliser per tree (grams applied per year)**		
	Superphosphate [1]	Potassium sulphate	Potassium Chloride [2]
1	210	350	450
2	420	700	900
3	630	1150	1350

4	840	1500	2000

[1] 11.3% P
[2] For comments on use of KCl (muriate of potash, potassium chloride) see section 2.8.3.2:conclusions.

- Apply phosphate in a single application in spring over the whole under-tree wetted area of the soil.
- With sandy soils, potassium applications can be split into 2 to 3 equal amounts, spread over the whole under-tree wetted area.
- Foliar applications of nutrient solutions can be made every 4 to 6 weeks if possible, to promote healthy vegetative growth. Zinc sulphate, copper oxychloride and Manganese sulphate at rates of 100 to 150 g per 100 litres water, can be added to 100 grams of Solubor and even 800g low biuret (spray grade: less than 0.6% biuret only) urea for an effective foliar spray, if needed. For more information on foliar applications, see section 2.7.3.ii below.

2.8.3.1. Quantity of fertiliser to be used.

S.N. Ghosh (2004) in West Bengal, India, made the following observations:

- Highest yield and fruit size recorded with oranges resulted from the following quantities of N, P and K, in grams per tree per year:

Element	For highest yield	For larger fruit	Nutrient Source
N	400g/tree/yr	300	Urea 46% N
P	150	100	Rock Phosphate: 23% P_2O_5
K	300	200	Potassium chloride: 58% K_2O

- Application of fertilisers were made in July and September in two equal splits
- Fertilisers were applied in a 30 cm wide circular band at a radial distance of 105 to 135 cm from the tree trunk
- Trees were basin watered with 30 litres per tree at 24 day intervals in the dry period of February to mid June
- Best results were obtained where trees also received application in July of 25 kg per tree of cow dung.
- Foliar applications of micronutrients (zinc 0.5% + boron 0.2% + iron 0.4%) increased fruit set, yield and quality
- Mulching of the tree basin with dry leaves was recommended.
- The observation was made that treatments that accentuated the February reproductive growth flush and maintained leafy trees through winter resulted in highest yield.

Table 10: *Recommended times and rates of N, P and K fertilisers for citrus mandarin trees in Punjab Province, Pakistan*

Application	Nutrient applied (active ingredient in grams/plant)
February	N at 350 g. a.i ./plant
April	N at 350 g. a.i. /plant
August/September	N at 300 g. a.i. /plant [Total N = 1000g a.i. per plant]
December	P at 500 g. a.i. , plus K at 500 g. a.i., plus Zn at 100 g. a.i. and farmyard manure at 40 to 50 kg/tree

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Table 11: *Rates and timings of N,P,K and Zn applications recommended for use on 'Kinnow' mandarin in the Sarghoda region of the Punjab*

Nutrient	Rate applied (in grams a.i. per tree)	Application times
N	750	Half the N, and all the P, K and Zn to be applied at the end of February. Apply the remaining half of the N during July
P	500	
K	500	
Zn	50	

Pakistani growers make extensive use of farmyard manures (FYM). These are considered a slow release form of nutrients that allow growers to reduce both **number** of fertiliser applications made each year, and amount of nitrogen per tree. However, one must know the **rate** at which nitrogen is released from manures by the natural process of mineralisation (accomplished best by soil microbes in balanced and healthy soil). Consider then the following table of data from Florida, USA:

Table 12: *Rate of release of nitrogen from poultry manure and human biosolids under soil and climatic conditions of Florida, USA*

Months after application	% available N as % of N applied	
	Poultry manure	**Biosolids**
0-1 month after	50	35
1-3	6	8
3-6	4	6
6-12	4	7
Total:	64	56

From this table we see that under the conditions of the trial roughly 2/3 of the N in poultry manure (i.e. 64%) and 1/2 of the N (i.e. 56%) in biosolids becomes plant available in the first year of application. Application of 100 kg of this poultry manure thus contributes 64 kg of N for plant use, and biosolids 56 kg N.

2.8.3.2. Timing of conventional fertiliser applications

i. Broadcast applications made to trees under flood, furrow or basin irrigation systems:

It is generally not necessary or wise to apply the entire annual nutrient requirement of the trees in one application. Growers are thus advised to make several applications or "splits" of fertiliser to their trees, at a time when trees are able to take up these nutrients for use at various critical phenological stages, such as flowering, fruit set, cell division and expansion and the onset of annual vegetative growth flushes. The recommended splits and timings of fertiliser applications are shown below.

Table 13: *Recommended splits (as percentage of the total annual requirement)of broadcast fertiliser to be applied at three phenological stages of citrus: flowering, fruit set and the fruit growth periods, for trees under flood, basin or micro-sprinkler irrigation systems.*

Element	% of total amount to be applied in the programme in the following stages		
	Bud swell to first flower buds seen	Cell division stage to physiological fruit drop	Cell enlargement phase
Nitrogen	**Apply 50%**	**30%**	**20%**
Phosphorus	**50**	**25**	**25**
Potassium	**50**	**25**	**25**
Calcium*	**60**	**20**	**20**
Magnesium	**50**	**50**	**-**

***Note: in this programme, use of single supers will supply 100% of the season's **calcium** requirement. It is also very cost efficient to apply supers and potassium sulphate in bands in August.

ii. Drip irrigation (fertigation) system applications: The following splits of fertilisers may serve as general recommended timings using conventional dripper fertiliser programmes. The more uniform the deliveries and water distribution patterns the more effective the application of fertiliser should be. Key periods shown are Flowering (January to March), fruit set (May) and summer monsoon (July to September).

Table 14: *Recommended splits (as percentage of the total annual requirement)of broadcast fertiliser to be applied at three phenological stages of citrus: flowering, fruit set and the fruit growth periods, for trees under drip irrigation (fertigation) systems*

Nutrients	Jan.	Feb	March	April	May	June	July	Aug	Sept	Total
Nitrogen	50%		25	10	10	5	0	0	0	100%
Phosphorus	70		10	10	10					100%
Potassium		60	10	10	10	10				100%
Calcium		60	15	15	10					100%
Magnesium			25	25	25	25				100%

- Consider the following **salinity potentials** of some common fertilisers: in this sodium nitrate is given a salinity potential of 100. The main reason why we do **NOT** use sodium nitrate as a fertiliser is because of its high salinity potential! Yet, we see here two fertilisers commonly used in citrus growing that have higher salinity potentials than sodium nitrate!

Fertiliser	**Relative salinity potential:**
Potassium chloride (KCl)	114
Ammonium nitrate	105
Sodium nitrate	100
LAN	98
Urea	75
Ammonium sulphate	69
Potassium sulphate	46
Double Superphosphate	10
Single Superphosphate	8

- Apply a **full irrigation** 2 to 3 days **before** applications of fertiliser (if soils are not wet through rain)
- Apply fertiliser and **irrigate-in** with 10 to 15 mm to wash the fertiliser **into** the root zone
- In sandy soils, withhold **heavy** irrigation for 7 to 10 days after fertiliser applications to reduce leaching losses

iii. Foliar fertiliser applications: Foliar applications certainly have a place in citrus fertiliser programmes, **providing suitable materials are used, and applications are done at the right time and in the right way**. Under certain situations, foliar fertilisers offer advantages in efficiency and effectiveness over ground-applied fertilisers:

- In waterlogged soils
- In cold soils with low root activity
- With trees having a restricted or diseased root system
- Where rapid uptake of nutrient is required
- With use of expensive materials

- Foliar applications are best applied to undamaged, young, fully expanded leaves from a recent leaf flush

ii. Additives to the spray mix. A number of additives exist that increase contact time and uptake by their effects on droplet surface tension and/or spray pH.
iii. Concentration of fertilisers used, assuming their compatibility in a mix. Effective concentrations reported vary greatly between the various authorities: table 15 shows a range of effective concentrations for nutrients and several classes of plant growth regulants.

Table 15: *Showing effective concentrations of a range of foliar applied nutrients and plant growth regulants commonly used in citrus.*

Effective concentrations (mg per litre: ppm) of spray materials

Nitrogen	4600	Zn	80 - 100
Potassium	>3800	Cu	15 - 25
Magnesium	800-1000	Cytokinins	10 - 20
Mn	375-500	Gibberellic acid	5 -10
B	300-400	Auxins	>5

(iii) Chemical formulation used. See comments above in (i) for "additives"

Standard timing for foliar sprays: NB: First CHECK **your** product labels for **precise rates** for usage. As a general guide for timing, consider the following:

Table 16: *Recommended timings for nutritional foliar sprays for citrus*

Nutrient	**Timing**			
	Winter	**Pre-blossom**	**Fruit set**	**Summer**
Urea	✔	✔		✔
Potassium nitrate			✔	✔
Magnesium nitrate		✔		
Zinc sulphate		✔	✔	
Manganese sulphate			✔	✔
Copper		✔		
Comments:	Urea supplies available N when roots are inactive	Apply to half expanded leaves	Best time is at about 80% petal fall	Apply to summer flush

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2.11. The Effects of nutrition on yield and fruit quality:

Growers should be able to recognise the **signs of nutritional imbalances** in their fruit: symptoms, which include the following:

Table 19: *Effects on citrus fruit quality factors of increasing levels of various nutrients and increased irrigations.*

Increasing levels of the nutrient shown within the recommended ranges result in the changes shown ("+" = increase; "0" = no effect; " – " = decrease; "?" = effect unknown). Note: **excess nutrition** can reduce yield and fruit quality

External fruit quality	Macronutrient					Micronutrient					Irrigation
	N	P	K	Ca	Mg	Mn	Zn	Cu	Fe	B	
External fruit quality											
Size	-	0	+	0	+	0	0	0	0	0	+
Mass	-	0	+	0	+	0	0	0	0	0	+
Green fruit	+		+	0	0	0	0	0	0	0	+
Peel thickness	+	-	+	0	-	0	0	0	0	0	-
Juice quality											
Juice %	+	+	0	0	0	0	0	0	0	0	+
Sugar content	+	0	-	0	+	0	0	0	+	0	-
Acidity	+	-	+	0	0	0	0	0	0	0	-
Vitamin C level	-	-	+	?	?	?	?	?	?	?	?
Juice colour	+	0	-	?	?	?	?	?	?	?	+
Peel blemishes											
Wind scar	-	+	0	?	?	?	?	?	?	?	+
Russet	-	-	0	?	0	0	0	0	0	0	0
Creasing	+	+	-	?	?	?	?	?	?	?	0
Scab	+	0	0	?	?	?	?	?	?	?	+
Storage decay											
Stem-end rot	-	0	-	?	?	?	?	?	?	?	-
Green mould	-	0	0	?	?	?	?	?	?	?	+

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