Technical Bulletin No. 31

Soil and Water Conservation, and Irrigation Management in Cashew

ಐಸಿಎಆರ್ - ಗೇರು ಸಂಶೋಧನಾ ನಿರ್ದೇಶನಾಲಯ
भा.कृ.अनु.प. – काजू अनुसंधान निदेशालय
ICAR-Directorate of Cashew Research
Darbe (P.O.), Puttur - 574 202
Dakshina Kannada, Karnataka, India

Soil and water conservation, and irrigation management in cashew

Shamsudheen Mangalassery

M.G. Nayak

Preethi. P

Muralidhara. B.M

Funded by

Rashtriya Krishi Vikas Yojana – Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR)

March, 2020

ಐಸಿಎಆರ್ - ಗೇರು ಸಂಶೋಧನಾ ನಿರ್ದೇಶನಾಲಯ

भा.कृ.अनु.प. – काजू अनुसंधान निदेशालय

ICAR-Directorate of Cashew Research

Darbe (P.O.), Puttur - 574 202

Dakshina Kannada, Karnataka, India

Citation:

Mangalassery, S., Nayak, M.G., Preethi, P. and Mualidhara, B.M. 2020. Soil and water conservation, and irrigation management in cashew, Technical Bulletin No. 31, ICAR-Directorate of Cashew Research, Puttur, Karnataka, India, p. 34.

Acknowledgements:

This publication is funded by Rashtriya Krishi Vikas Yojana – Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR), Government of Karnataka.

Published by:

Dr. M.G. Nayak
Director (Acting)
ICAR-Directorate of Cashew Research
Puttur – 574 202, D.K., Karnataka
Tel: 08251-230902 Fax: 08251-234350
Email: director.dcr@icar.gov.in
Website: https://cashew.icar.gov.in

13 March 2020

Printed at:

Codeword Process and Printers
C - 18, Yeyyadi
Mangaluru– 575 008
Tel. No.: 0824-2214618, 9900100818
E-mail : codeword.process@gmail.com

Preface

Cashew (*Anacardium occidentale* L.), is predominantly cultivated in the poor fertile soils along the West and East coast of India under humid tropical climate. It is raised rainfed with the limited supply of irrigation water and is considered as one of the hardy crops of the tropics. The research studies showed that providing irrigation can substantially increase the nut yield in cashew. The high irrigation response of the tree is due to the fact that the flowering and fruiting in cashew occurs during the dry season in India.

ICAR-Directorate of Cashew Research and co-ordinating centres of AICRP on cashew have developed many useful technologies and recommendations for addressing water management issues in cashew. This bulletin covers the various aspects of water management in cashew, which includes soil and water conservation alternatives for the regions with limited access to irrigation water, protective irrigation and detailed account on drip system of irrigation.

The compilation includes research findings from previous researchers, scientists and extension workers and authours thankfully acknowledges their contribution to the science of water management.

This bulletin entitled “Soil and water conservation, and irrigation management in cashew” is funded by Rashtriya Krishi Vikas Yojana – Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR), Government of Karnataka and authors sincerely thank the authorities for the financial assistance.

Shamsudheen Mangalassery
M.G. Nayak
Preethi. P
Muralidhara. B.M

Date : 13 March 2020
Place : Puttur

CONTENTS

SOIL AND WATER CONSERVATION, AND IRRIGATION MANAGEMENT IN CASHEW

1. Introduction

Cashew is one of the important foreign exchange earning crops and is traditionally grown in the coastal regions in India. The major cashew growing states along the west coast are Maharashtra, Goa, Karnataka and Kerala. Along the east coast, the major cashew growing states are Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. The non-traditional areas of cashew cultivation are Bastar region of Chhattisgarh and Kolar (Plains) regions of Karnataka, Gujarat, Jharkhand and in NEH region. In India, cashew is generally grown as a rainfed crop mainly along the coastal areas in low fertile soil. Majority of cashew orchards in India are not irrigated. The productivity levels of cashew are low in India compared to other producer countries. The research studies showed that the mean rainfall distribution in cashew area ranged from low rainfall (1500-2000 mm in Gujarat) to high rainfall (2700 to 3500 mm in west coast and NEH region). In India, the vegetative development of cashew occurs during the rainy season and the reproductive phase during the dry season. Although cashew is grown in high rainfall environment, it experiences severe moisture stress during January to May with the highest water deficit from March to May. Incidentally, the critical growth phases such as flushing, flowering and nut formation in cashew also occur during these periods. Any form of biotic and abiotic stresses during these periods adversely affect the flowering and fruit set and result in premature nut drop and finally reduces the yield and productivity of cashew. Lack of moisture availability during the fruiting season is one of the several factors associated with the low yield in cashew. Studies have shown that supplemental irrigation can significantly improve the productivity and yield of cashew. This bulletin addresses various issues in water management in cashew. The bulletin highlight the importance of water management in cashew, different options available to address the issue of irrigation, water conservation and water management for increasing the yield.

2. About cashew

Cashew (*Anacardium occidentale* L.), is native to Brazil and was introduced to India by Portuguese travellers as a soil binding crop, to control soil erosion in coastal areas during 16th century. Sooner its commercial importance and adaptability to adverse soil and environmental conditions were recognised and its cultivation on commercial scale occurred along the East and West coast of India. Export of cashew kernels and cashewnut shell liquid bring foreign exchange to the country. In India, cashew is cultivated on a wide range of soil types such as sandy to sandy loam, laterite soil, loam and red latosols. Due to its drought hardiness, cashew is widely cultivated in degraded hillocks and slopy lands, where profitable production of other crops is not possible (Fig. 1). Majority of cashew growing soils are low in soil fertility in terms of nitrogen, base status, cation exchange capacity and micronutrients such as zinc and boron. Due to heavy precipitation in the coastal areas where cashew is grown, the basic cations are washed out causing increased soil acidity. The high soil acidity, in turn, decreases the nutrient uptake by the plant, making some of the nutrients unavailable for cashew.

Fig. 1. Cashew grown on hillocks

2.1. Cashew growing areas in India

The major cashew growing states in the west coast are Maharashtra, Goa, Karnataka and Kerala. Along the east coast, the major cashew growing states are Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. The non-traditional areas of cashew cultivation are Bastar region of Chhattisgarh and Kolar (Plains) regions of Karnataka, Gujarat, Jharkhand and in NEH region. The major districts in different states of India cultivating cashew are given in Table 1.

Table 1. Cashew growing districts in different states of India

State	Cashew growing districts
Kerala	Palakkad, Malappuram, Kozhikode, Kannur, Kasaragod
Karnataka	Kolar, Shivamogga, Belagavi, Uttara Kannada, Dakshina Kannada, Udupi, Kodagu, Gadag, Bidar, Chikmagalur, Tumkur, Hassan
Goa	Entire state
Tamil Nadu	Ariyalur, Cuddalore, Pudukkottai, Villupuram, Theni, Thirunelveli, Sivagangai
Andhra Pradesh	Sreekakulam, Vizianagaram, Vishakhapatanam, East Godavari, West Godavari, Guntur
Odisha	Baleshwar, Cuttack, Dhenkanal, Ganjam, Kandhamal, Kendujhar, Koraput, Mayurbhanj, Puri, Sambalpur, Sundargarh, Angul, Khordha, Nayagarh, Malkangiri, Nawarangpur
Maharashtra	Thane, Raigad, Ratnagiri, Sindhudurg, Kolhapur, Nasik
Chhattisgarh	Bastar, Dantewada, Raigarh, Narayanpur
West Bengal	Burdwan, Birbhum, Bankura, Puruliya, Midnapore (W), Midnapore (E)
Jharkhand	East Singhbhum, West Singhbhum, Saraikela
Meghalaya	East Garo Hills, West Garo Hills, South Garo Hills
Tripura	South Tripura
Assam	Dhubri
Gujarat	Navsari, Valsad, Dong

As per the latest statistics (2017-18), Odisha occupy the largest area under cashew (1.94 lakh ha), followed by Maharashtra (1.91 lakh ha), Andhra Pradesh (1.87 lakh ha), Tamil Nadu (1.42 lakh ha), Karnataka (1.29 lakh ha), and Kerala (0.92 lakh ha). Whereas the production of cashew nut follows the order Maharashtra (2.69 lakh tonnes)> Andhra Pradesh (1.16 lakh tonnes) > Odisha (0.99 lakh tonnes) > Karnataka (0.89 lakh tonnes) > Kerala (0.88 lakh tonnes) (Table 2).

Table 2. Area, production and productivity of cashew during 2017-18 in different states of India (DCCD, 2018)

State	Area (000 ha)	Production (000 mt)	Productivity (kg/ha)
Kerala	92.81	88.18	962
Karnataka	129.07	89.45	672
Goa	58.25	34.26	561
Maharashtra	191.45	269.44	1378
Tamil Nadu	142.28	71.03	478
Andhra Pradesh	186.78	116.92	600
Odisha	193.99	98.59	513
West Bengal	11.36	12.96	1140
Chattisgarh	13.70	9.83	681
Jharkhand	14.83	6.13	393
Tripura	4.25	3.45	812
Meghalaya	8.58	6.12	686
Assam	1.05	1.13	1028
Gujarat	7.25	6.50	900
Pondichery	5.00	2.16	432
Manipur	0.90	0.32	360
Nagaland	0.50	0.54	1080

2.2. Climatic features of cashew growing areas in India

The total rainfall of cashew growing regions varies much. It can grow in regions receiving rainfall as low as 300 mm (Gujarat) to >3500 mm (Maharashtra and Kerala). However, the rainfall range of 600 to 1500 mm was shown to be good for increased yield. Regions receiving few light showers of rains during January to March further benefit to realise increased yield. The average minimum temperature in cashew growing areas ranges from 10 to 22°C and average maximum temperature from 32 to 40.1°C.

3. Water requirement of cashew

In India, the vegetative development of cashew occurs during the rainy season and the reproductive phase during the dry season. Although cashew is grown in high rainfall environment, it experiences severe moisture stress during January to May. The critical growth phases such as flushing, flowering and nut formation in cashew also occur during these periods. Any form of stress either biotic and abiotic stresses during these periods adversely affect the flowering and fruit set and result in premature nut drop and finally reduces the yield and productivity of cashew.

4. Water management in cashew

The cashew growing regions are characterised by high intensity rainfall over a short duration which leads to runoff and soil erosion. Cashew experience moisture stress during December/January to May which coincide with flowering and fruit setting phase of cashew, leading to flower drying and immature nut drop. Moreover, the traditional areas of cashew cultivation (hillocks and sloppy laterite terrains) lack access to water sources for irrigation purposes. Research studies indicate that cashew though a hardy crop responds well to water and manure management. In areas with no access to irrigation water, the water deficit to the crop can be managed to some extent by the adoption of region-specific soil and water conservation practices. Adoption of such practices is part of cashew production technology in case of slopy areas to prevent surface runoff and soil erosion.

5. Soil and water conservation practices

Cashew plantations are raised on landscapes which are unsuitable for many other crops, and generally lack a source of water for irrigation. Arranging irrigation in such landscapes will be a difficult and costly affair. Adoption of proper soil and water conservation techniques in-situ in such slopy and degraded landscapes play a very important role in preventing further soil degradation by controlling soil erosion, conserving soil moisture and improving tree growth and productivity in a sustainable manner. Among different soil and water conservation techniques studied, modified crescent bunds, staggered trenches with coconut husk burial and reverse terrace are recommended for cashew orchards. The other popular soil conservation practice recommended for cashew is a terrace with catch pits. These practices were found to be beneficial to harvest pre-monsoon rainfall and increase the cashew yield to the tune of 32-35%. Other benefits are reduction in runoff velocity and soil loss, increased soil moisture retention and groundwater recharge. With the adoption of such soil and water conservation practices, barren/slopy lands can be brought under cashew cultivation in order to increase the farm income and land productivity.

Different technologies for in-situ soil and water conservation recommended for cashew are detailed below. The adoption of these practices should be done in accordance with the local conditions, topography, water holding capacity and infiltration characteristics of the soil, and the cost consideration.

5.1. Trenches/engineering measures

5.1.1. Continuous bench terraces: Terraces stop the downslope soil and water movement and also give the advantage of providing a flat surface for the planting of cashew, thereby further reducing the possibility of erosion (Fig 2).

Fig. 2. Continuous terraces

5.1.2. Continuous contour trench: These trenches are taken in slopy areas (7 to 8% slope), running through entire field length along the contour. The trench dimension recommended is 0.5 m x 0.6 m.

5.1.3. Modified crescent bund: The modified crescent bund consists of a crescent-shaped bund of 6 m length, 1 m width and 0.5 m height at 2 m radius, which is to be taken at upstream of the cashew terrace which will help to retain water as well as litter (Fig. 3 and 4).

Fig. 3. Modified crescent bund for soil and water conservation in cashew orchards

Fig. 4. Terrace with crescent bund

5.1.4. Staggered trench: The staggered trenches of size 5 m length, 1 m width and 0.5 m depth are to be taken between two rows of cashew or in the middle of 4 plants, across the slope, in which coconut husks can be buried to enhance water retention (Fig. 5).

Fig. 5. Staggered trenches between two rows of cashew plants

5.1.5. Reverse terraces: The recommended dimensions for reverse terraces are 2 m length, 2 m width and 0.7 m depth, which are constructed so as to be inclined from periphery to the centre (Fig. 6).

Fig. 6. Reverse terrace for soil and water conservation in cashew orchards

5.1.6. Catch pits: The recommended dimensions for catch pits are 3 m length, 0.5 m width and 0.5 m depth, which are constructed upstream of cashew planted terrace, to catch and retain the runoff and to increase percolation (Fig. 7 and 8).

Fig. 7. Catch pit

Fig. 8. Terrace with catch pits for soil and water conservation in cashew in steep slopes

5.1.7. Tree base terrace: Formation of tree base terrace at 2 m radius around the plant, taken over three years of planting shall be beneficial for moisture conservation. It is made by taking soil from the upper side of the slope and filling at the lower portion. The upside shall be taken in such a way that it forms a catch pit to deposit soil and conserve moisture.

5.2. Bioengineering measures

5.2.1. Coconut husk burial: Adoption of coconut husk burial techniques with soil and water conservation techniques like modified crescent bund, staggered trenches etc. improve the water retention in the soil for longer periods. This practice of coconut husk burial can be adopted around the cashew plants also. Husks are to be buried in trenches of 3.5 m length, 1 m width and 0.5 m depth, opened across the slope between two rows of cashew. In such trenches, 3 to 4 layers of husks can be buried with the convex side of the first layer of husk touching ground. The last layer of husks should be placed with the convex side upper side. A thin layer of soil and leaf materials can be placed between layers of husks. Then the trench can be filled with soil, leaving about 10 cm depth (Fig. 9 and 10).

Fig. 9. Coconut husk burial for soil and water conservation in cashew orchards

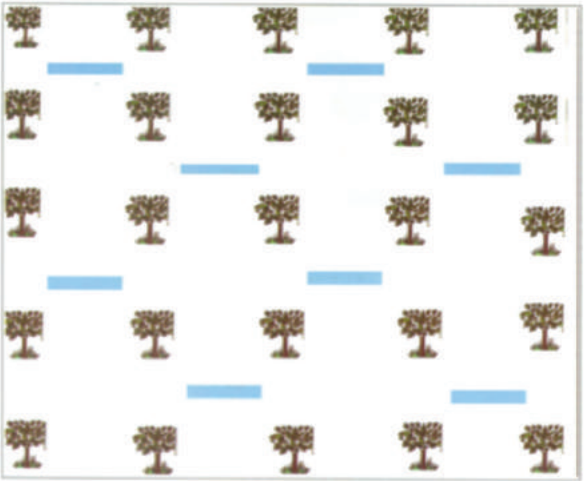

Fig. 10. Schematic representation of coconut husk burial in staggered trenches (After Yadukumar and Rejani, 2008)

5.2.2. Use of bigger pits and mulching: This practice is to be followed during the establishment of cashew plantations. Pits of 1 m^3 size are to be dug open at recommended spacing following other soil and water conservation measures such as terracing. These pits are to be filled with topsoil, organic manure and rock phosphate at recommended rate up to 2/3rd depth. Plant the graft at the centre of this pit and proper mulching is to be done.

5.2.3. Trenches with vegetative barriers: Inclusion of vegetative barrier along with continuous contour trenches and staggered trenches (in reversely slopy areas) can substantially reduce runoff and soil loss. *Stylosanthes hamata, Vetiveria zizanioide*s are some of the recommended vegetative barriers. Apart from helping to reduce runoff and soil loss, the vegetative barriers can be harvested to provide additional income.

5.2.4. Green manuring and mulching: Growing green manure crops like *Glyricidia* at vacant spaces and borders provide material for mulching. Mulching the tree basin with green mulch helps to conserve the soil moisture.

2.5. Circular trench with leaf litter and coconut husk: This practice is generally recommended for east-coast areas, wherein coconut husks and leaf litter are buried in circular trenches of 0.3 m width and 0.5 m depth opened at 2 m away from the cashew trunk (Fig. 11).

Fig. 11. Circular trench with leaf litter and coconut husk

6. Supplementary/protective irrigation

6.1. Protective irrigation

While establishing the new plantations, the planted cashew grafts require enough soil moisture for the initial establishment and hence it is recommended to plant the cashew grafts during the monsoon season. Under drought situation, the newly planted grafts need to be watered once in every 2 to 7 days, to ensure the root ball of the graft is kept moist, but not waterlogged. Once established, due to the deep taproot system, the cashew trees can survive the moderate dry season without irrigation, but with an adverse effect on yield. Cashew is known for its drought hardiness and generally grown as unirrigated, however, the yield can be increased if irrigated. Wherever the source of irrigation water is available, providing supplementary irrigation can benefit for improving the nut yield.

Providing irrigation @200 litres per tree at 15 days interval during November to March increases the nut retention and yield. For yielding trees, protective irrigation is to be given only after the plant enters the flowering phase, during nut set and nut development stages.

By providing black polythene mulch the quantity of irrigation to be provided can be reduced to 60 L/tree once in a fortnight.

6.2. Drip irrigation

In drip system of irrigation, water is applied through a network of pipelines and applied to the root zone of crop drop by drop by use of emitters or drippers. In this system, water is applied based on ET demand of the crop and root zone is always maintained at field capacity levels.

Drip irrigation allows water saving to the tune of 40 to 70% in comparison to other methods of irrigation and 25-80% increase in yield when practiced with other cultural practices. The water requirement in cashew is decided based on the climatic condition, canopy area and growth phase of the plant. Based on canopy coverage and daily water evaporation, the water requirement of cashew can be calculated as follows.

To meet 20% CPE

Age of tree: 5 years

Canopy spread or diameter: 4 m [mean of EW and NS length of canopy]

Ground coverage of canopy: $\pi r^2 = 3.14 \times 2 \times 2 = 12.56\ m^2$

Daily CPE = 5mm; 20% CPE = 1 mm

The quantity of water to be given to meet 1 mm of water in 12.56 m^2 area = $12.56 \times 1/1000 = 0.01256\ m^3$.

$1\ m^3 = 1000$ L

$0.01256\ m^3 = 12.56$ L/tree/day

Advantages of drip irrigation

- It reduces direct loss of water by evaporation, seepage and percolation.
- Slow application rates facilitate easy infiltration to the soil.
- It reduces water consumption by weeds and grasses.
- It allows watering in the root zone of the plant.
- Yield increases due to optimum soil moisture status at the root zone.
- It can be adopted in undulating areas, where surface methods of irrigation are not possible.
- Increased water use efficiency.

Disadvantages of drip irrigation

- The drippers are clogged with soil/mineral particles and algae.

- The soil moisture is limited and depends on the discharge of drippers, dripper spacing and the soil type.
- The rodents and insects may damage some of the components of the drip system.
- The initial investment and annual maintenance cost are higher compared to other irrigation methods.

6.2.1. Main components of the drip system

The main components of the drip system are:

6.2.1.1. The water source: The water source can be a well, river, lake etc. The water used in drip irrigation should be clean to avoid clogging of emitters and laterals due to physical, chemical or biological agents. Almost all water sources contain the polluting agents that aid in the growth and development of bacteria and algae. Use of filtering devices can help to remove the polluting agents to some extent.

6.2.1.2. The overhead tank or pump and the power supply: The pump should be chosen such that it provides required pressure for working of the drip system being installed in the field.

6.2.1.3. Mainline: It is used to take water from the source to the field. Usually, it is laid below the soil surface to avoid damage due to heat and UV rays. These are mainly of PVC or HDPE and of 30 to 75 mm diameter with 4-10 kg/cm^2 pressure. These pipes are to be laid at a depth of minimum 2 feet below the ground surface to avoid the damage while carrying out the farm operations.

Fig. 12. Laying the main line of the drip system

6.2.1.4. Sub mainline: It is intended to supply water to the lateral pipes from the main lines and is usually of 25 to 40 mm diameter and 4 kg/cm^2 pressure. These are also mostly buried inside the soil and are connected to the mainline using fittings such as Tee, elbow etc.

6.2.1.5. Filtration systems:

The filtration system is an essential part of the drip irrigation system. It help to prevent the entry of clay, soil, gravels and other organic and inorganic contaminants present in the irrigation water into drip pipelines. Common filters are sand filter, disc filter, screen filter and hydro cyclone filter.

a) Sand filter: Sand filters are useful when the water source is well or river where the water is expected to contain solid particles (25-200 microns) and algae (Fig. 13). Due to heavy nature, providing cement concrete foundation for the sand filter unit shall be helpful to reduce vibration and resultant damage to the filter. In this filter, the water from the source is allowed to enter through the top and allow passing through layers of sand filled on the top layer and then through gravel-filled at the bottom layer, during the process, the particles get adhered to the sand and gravel. Due to continuous use, the efficiency of sand bed in the filtration system reduces as the solid contaminants clog the pore space. Occasionally the sand filter needs to be cleaned by backwashing, by the forceful flow of water in opposite direction. Backwash flow force should be such that it will not lead to the removal of sand. It is also beneficial to stir the sand when backflush operation is on. The sand used in the sand filter also needs to be replaced with fresh sand at regular intervals.

Fig. 13. Sand filter

b) Disc filter: Disc filter consists of a series of discs made up of poly propylene and is useful to remove the dirt, algae and other particles in irrigation water. It is connected to the mainline after the sand filter (Fig. 14). It is preferred over screen filters due to the cost-effectiveness and provision for backwashing. They can be cleaned by taking out of the filtration assembly and clean with flowing water.

Fig. 14. Disc filter

c) Screen filters: It is used to remove the sediments and debris from the irrigation water (Fig. 15). It is also connected after the sand filter. It consists of a pipe with mesh screen with perforations of diameter up to 200 microns. Occasional cleaning is required by removing the screen filter and careful cleaning with a soft brush.

Fig. 15. Screen filter

d) Hydrocyclone filters (Centrifugal filters): It is required to be used when the water source contains significant amounts of sand (Fig. 16). It is used to remove the sand and small stone particles from the irrigation water. When water flows with force through a conical device, the heavy particles in the water are thrown to the sides and subsequently get accumulated in the tank installed below.

Fig. 16. Hydrocyclone filter

Installation of filter station

Suitable brick masonry or cement concrete platform need to be provided to keep the filter system and the fertigation unit. For 1.5" sand filter, the recommended platform size is 5x3 feet. While providing the platforms and overhead protection if any, it must be ensured that adequate space is available for cleaning the filters and filling/ emptying of fertigation/filtration units.

6.2.1.6. Fertigation system and chemigation equipment

Fertigation is the technique of providing fertilisers in liquid form along with drip irrigation.

Different types of fertiliser application devices to use with the drip system are available.

a) Venturi injector: It has a converging section, throat and diverging section. When the flowing water passes through the throat section, its velocity increases and pressure reduces creating suction, by which the liquid fertilisers are sucked into the drip system from the fertiliser tank. The venturi is operated by creating a pressure difference between entrance and exit gauges using pressure regulating valves (Fig. 17). The flow rate of fertiliser to the drip system is adjusted using valves. Usually, the differential pressure to be created for the venturi system to work is 20%. The venturi pipe is to be fitted in parallel to the water pipeline connected to the filter and the tube at the centre of venturi pipe is to be dipped in the fertiliser stock solution. When water flows through the venturi, the velocity of flow increases, causing reduction in pressure resulting in the creation of a vacuum, and thereby sucking of the fertiliser solution and its injection to the drip pipeline system. The main disadvantage is the fertiliser suction variation due to variation in water pressure.

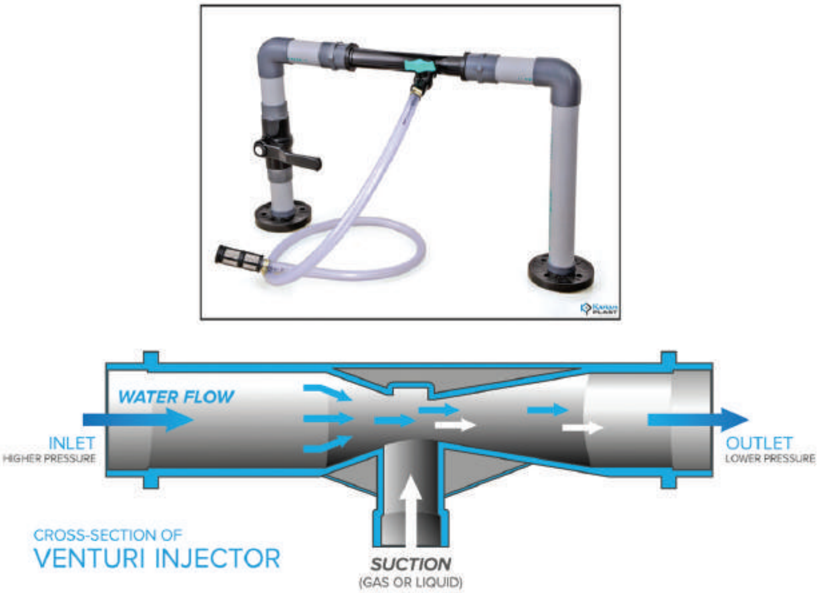

Fig. 17. Venturi in fertigation

b) Fertiliser tank method: It uses a tank into which fertiliser stock solution is filled (Fig. 18). The tank should be big enough to hold the fertiliser solution required for the planted area. In this system, the mainline flow is diverted through a tank containing fertiliser liquid or soluble solid fertiliser causing dilution of fertiliser and the diluted fertiliser is allowed to flow back to the mainline for fertigation. Pressure reducing valves are used to regulate the water flow through fertiliser tank. The main disadvantage of this system is that the concentration of fertiliser changes over a period of time. The concentration will be more at the beginning.

Fig. 18. Fertiliser tank

c) Fertiliser injection pump: In this, a pump is used to transfer the fertiliser stock solution from the fertiliser storage tank and inject under pressure into the irrigation system. The pumping rate can be very well controlled by using this system (Fig. 19).

Fig. 19. Fertiliser injection pump

6.2.1.7. Automation system/Irrigation control systems: This includes various control valves and safety valves.

a) The pressure gauge: It measures water pressure in the drip system and is used in case of non compensating pressure drippers.

b) The pressure regulator/pressure relief valve: It can be fixed or adjustable and help to compensate for the changes in elevation or frictional losses. Automatic flow valves reduce pressure variations among lateral lines in uneven land.

c) Air relief valve or vacuum breaker: It is used to remove air from the drip irrigation system. The vacuum created when the irrigation system is shut off can obstruct the water flow. Vacuum breaker of one inch for each 25 gpm of flow is recommended.

d) Flushing valve: The flushing valve at the end of each lateral helps in flushing of the system. It should be fixed horizontally after providing an elbow so that water will not be spread on the person while flushing.

6.2.1.8. Laterals: Low Density Poly Ethylene (LDPE) or Linear Low Density Poly Ethylene (LLDPE) pipes of smaller diameter are used as lateral pipes (Fig. 20). It can resist adverse weather conditions for a long period of time and are hence placed on the soil surface. It is on these pipes, the emitters are fitted (Online lateral). These pipes are usually 12 to 20 mm diameter, 1-3 mm thickness and 4 kg/cm^2 pressure which can be bend easily. Nowadays In-line lateral pipes are also available, where the emitters are pre-fitted inside the pipes.

Fig. 20. Lateral pipes used in the drip irrigation system

6.2.1.9. Emitting devices such as drippers or micro spray heads: These are the ultimate water supplying units of a drip system and are connected to laterals. It is important to choose emitters according to the water requirement of the crop, which is also long-lasting and clogging preventive. The emitters of flow rate ranging from 2 to 20 litre per hour are available in the market. Pressure compensating emitters are also available which automatically adjust the water flow based on variations in pressure in the pipeline.

Fig. 21. Drippers/emitters

Clean water is essential for the drip irrigation system. Use of poor quality water can leads to blockage of emitters and laterals. The water from the pump is distributed to the field through the mainline. The secondary lines take water from mainline to the lateral lines and lateral lines supply water to the drippers, which in turn supply water in the root zone.

6.2.2. Drip irrigation schedule for cashew

In cashew, for yielding trees, the drip irrigation can be started from the second fortnight of November/December to end of March, depending on the variety. However, for new plantations, irrigation can be continued throughout the summer period. For well established normal density plantations, the rate of drip irrigation recommended is to meet 60% of the evaporative demand. In general, this can be met by providing 4 drippers with each of 6 L/h capacity, running for 1.5 hours (that provide 36 litres of water per tree per day) during December and January. The general recommendation during February and March under normal density planting is to provide 48 L/tree/day (4 drippers of 6 L/h capacity, running for 2 hours). These rates are for grown-up trees.

In case of high density planting system, drip irrigation is to be given to meet 20% of the evaporative demand. This is provided by installing two drippers each of capacity 2 L/h at the base of the tree located at 1 m equidistance from the base of the tree, running for 1 h 45 minutes (giving 7 litre water per tree per day) during December and January and running for 2 h 15 minutes (giving 9 L water per tree per day) during February and March.

Irrigation should be started only after flowering and stopped before starting the harvest. When the drip system is planned right from the establishment of plantations, two drippers can be placed at 0.5 m away from the base of the tree on both sides on the lateral pipe, and another two drippers 1 m away from the base of the tree on both sides of the cashew tree. Microtubes of 1.5 to 2 m length can be connected to the drippers to facilitate changing the water dripping points near the root zone as the tree grows up over different years (Fig. 22).

Fig. 22. Installing the drippers in the lateral line for cashew

6.3. Fertigation

It is the technique of applying plant nutrients by dissolving them in irrigation water mainly through the drip system. It helps to deliver the correct quantity of water and nutrients to plant roots zone. Fertigation ensures almost 90% use efficiency for the applied fertilisers, as it enables applying the nutrients at the most nutrient demanding stage of the crop, at the right place (at the zone of highest root activity) and the right time. The right combination of water and nutrients is to be used to obtain desired results through fertigation. The advantages of fertigation are as follows.

- Higher nutrient use efficiency.
- Less pollution of water bodies through leaching of fertiliser nutrients.
- Savings of water, nutrients, energy, labour and money
- Effective application of micronutrients.
- Reduced weed growth.
- Increased yield and quality of the produce.

The disadvantages of fertigation is given below.

- Chances of non-uniform distribution of fertilisers to different trees in case of any fault in the drip irrigation system.
- Clogging of emitters/laterals pipes due to precipitation of chemicals.

6.3.1. Fertilisers for use in fertigation

Liquid fertilisers are best suited for fertigation. However, they are not readily available and are expensive. While using the solid fertilisers, their solubility in water and compatibility among each other is to be ascertained. The fertiliser compatibility chart is given below (Table 3). The problem of non-compatibility can be addressed by the use of different mixing tanks or applying the fertilisers at different times.

Table 3. Compatibility of the most common soluble fertilisers

	Urea	Ammonium nitrate	Ammonium sulphate	Mono ammonium sulphate (MAP)	Monopotassium phosphate (MKP)	Potassium nitrate	Potassium sulphate	Potassium chloride	Calcium nitrate	Magnesium sulphate	Soluble boron
Urea	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ammonium nitrate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ammonium sulphate	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y

Mono ammonium sulphate (MAP)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y
Monopotassium phosphate (MKP)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y
Potassium nitrate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Potassium sulphate	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Potassium chloride	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Calcium nitrate	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Magnesium sulphate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Soluble boron	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Source: Fertigation, Scott and Rockester 2012

6.3.2. Amount of fertiliser to use

The amount of fertiliser to be applied in fertigation depend on fertigation frequency, soil type, crop nutrient requirements and nutrient content in the soil. The amount of fertiliser to be applied in fertigation is calculated as follows.

Nutrient requirement (kg/ha) = Recommended dose of fertiliser for the crop kg/ha x Correction factor

The correction factor is to account for leaching, run-off, volatilisation and adsorption losses. The correction factor for N, P and K fertilisers are given in Table. 4.

Table 4. The correction factor for N, P and K fertiliser

Sl No.	Nutrient	Correction factor
1	Nitrogen	1.1 to 1.2
2	Phosphorus	1.6 to 1.9
3	Potassium	1.2 to 1.4

6.3.3. Frequency of fertigation

The fertigation can be undertaken daily, alternate days or at weekly intervals, which depend on system design, soil type, nutrient requirement and the convenience of the user. The total water application rates including fertigation should be in accordance with crop water and nutrient requirements. Also, it is to be ensured that nutrients applied in one irrigation should not be subjected to leaching during the same or subsequent irrigations.

6.3.4. Injection duration

The duration of fertiliser injection depends on soil types and nutrient and water requirements of the crop. The injection time should also cover the time to flushing out of fertiliser residues from the drip lines before switching off the pump and the recommended duration is 45 to 60 minutes. Application of too much water should be avoided as it may leach the nutrients out of the root zone or lead to excessive wetting of the soil.

6.3.5. Concentration

The concentration of chemicals to be supplied through the fertigation system need to be kept low to avoid precipitation and clogging inside the system. The suggested concentration range for fertiliser and chemicals is 200 to 500 ppm and for bactericides, it is 0.5 to 10 ppm.

While applying the fertiliser through fertigation, it is important to see that nutrients in the irrigation water are within the acceptable limit for plant uptake. Applying fertiliser lower or higher than plant requirements could result in poor plant growth. The nutrient concentration in irrigation water depends on plant requirement and the fertiliser material used in fertigation. The general acceptable limits of concentration of nutrients are given in Table 5.

Table 5. The general acceptable limits of concentration of nutrients [After Anonymous, 2015]

Sl. No.	Nutrients	Range of acceptable limits of concentration (ppm)	Average acceptable concentration (ppm)
1	Nitrogen	150-1000	250
2	Phosphorus	50-100	80
3	Potassium	100-400	300
4	Calcium	100-500	200
5	Magnesium	50-100	75

6	Sulphur	200-1000	400
7	Copper	0.1-0.5	0.25
8	Boron	0.5-5.0	1.0
9	Iron	2.0-10	5.0
10	Manganese	0.5-5.0	2.0
11	Molybdenum	0.01-0.05	0.02
12	Zinc	0.5-1.0	0.5
13	Sodium	20-100	50
14	Carbonates	20-100	60
15	Sulphate	200-300	250
16	Chloride	50-100	70

6.3.6. Preparation of stock solution

Calculate the fertiliser requirement for fertigation schedule as below:

Final % of fertiliser in stock solution = [(Amount of particular fertiliser x % nutrient content)/100]/capacity of tank used x 100.

Final ppm = Final % x 10,000

6.3.7. Fertilisers used in fertigation

The fertilisers used in fertigation should be readily soluble in water, compatible with other fertilisers, low content of insoluble matters and low corrosiveness. The general thumb rules on solubility are given below.

- All ammonium, nitrate, potassium, sodium and chloride salts are soluble.
- All sulphates are soluble except for calcium sulphate.
- All oxides, hydroxides and carbonates are insoluble.
- Urea, MOP and chelated micronutrients are generally soluble.
- Phosphates, sulphates, calcium, magnesium and trace elements may lead to precipitation and blocking if mixed or used with hard water (high in calcium and

magnesium). For example, ammonium sulphate causes precipitation of calcium sulphate and magnesium as sulphate.

- Tracer elements such as Mg, Zn, B, Fe, Cu etc., are difficult to apply through drip irrigation because they need in very low quantities, may react with salt in water and causes clogging. However chelated form such as Fe- EDDHA, Fe-DTPA can be used, as on chelation the solubility increases.
- Custom made liquid Liquid fertilizer designed for fertigation are also available in the market, however, this may be costly.

When fertilisers are solubilised by mixing, they may react and tend to precipitate, if they are not compatible. Such fertilisers are better applied separately through fertigation on different days/time or through different fertilisation tanks. Examples of such incompatible fertilisers are Ammonium sulphate and potassium chloride; calcium nitrate with phosphates or sulphates or DAP, MAP; Phosphoric acid with iron, zinc, copper and manganese etc.

6.3.8. Dissolution of nutrients to prepare the stock solution

The nutrient stock solution of fertiliser is prepared by dissolving the selected fertiliser in a tank in water. The fertiliser may be dissolved together or separately as per the solubility. The stock solution can be prepared each time or together. Tanks of suitable capacity depending upon the frequency of fertigation, area or no. trees to be irrigated, application rate and concentration can be used.

6.3.9. Precautions in fertigation

Before the start of fertigation, make sure that the backflow prevention arrangements are in place and working. The total time to be taken into account while fertigation includes the following:

- Time for water to travel from the injection point to the farthest emitter and bring the system up to full pressure: In small irrigation units the full system pressure is about 8-12 psi and achieved in less than 15 minutes.
- Time to inject the fertilizer solution: Begin the fertigation once the system reaches the full pressure. In sandy soil, the run time should not be more than 1.5 hrs to avoid leaching.
- Time for the last bit of fertilizer solution to reach the farthest emitter.

- Additional time to flush the system.

In well-planned orchards under high density planting system, higher yield and returns from the unit area could be achieved by nutrient and water application through fertigation along with appropriate canopy management. Fertigation can save 50% of the fertiliser requirement while increasing the cashew yield, especially during the early years of plantation under high density planting in comparison to normal planting.

6.3.10. Fertigation recommendation in cashew

It has been reported that fertigation can save upto 50% of the fertilizer requirement. Under fertigation, only 50% of the recommended dose of fertiliser be given through drip and remaining may be applied in the form of castor cake (4 kg/tree/year in case of normal density planting system Or 2 kg castor cake per tree per year in case of high density planting system). The application of organic manure or castor cake may be done during August in pits dug out near water dripping point located 1 m distant from the base of the trees. The recommended dose of fertiliser needs to be given in equal splits at weekly interval starting from October to February. The required quantity of fertilisers is to be dissolved in water and applied through the drip system.

Immediately after the cessation of monsoon rains, the flushing phase gets intensified in cashew and fertiliser application is essential during this phase. However, since flowering induction in cashew needs dry period, irrigation is not recommended during these periods. So to meet the nutrient demand, 25% of the recommended dose may be applied as basal dose as a soil application. Rest of the dose may be applied in equal split doses at weekly intervals starting from October up to February. For young and establishing plantations irrigation can be given at 100% CPE during summer months.

However, under the actual field conditions, the no. of drippers, flow rate, availability of labour to run the system daily, age of the cashew trees, its development stages etc vary widely and user needs to customise his/her requirement. Similarly in designing fertigation schedule, the field conditions vary widely under each farmer’s field and a general recommendation may not be useful. The availability of fertiliser, soil conditions, density of planting, age of the tree etc needs to be taken into consideration while formulating a fertigation schedule. To empower the users to do drip/fertigation calculations and scheduling at their convenience by inputting their specific needs and resources, software and mobile App is being developed by ICAR-Directorate of Cashew

Research, Puttur and will be shortly available on ICAR-DCR website and Google Play store.

6.4. Maintenance of drip system

6.4.1. Daily maintenance

- Start the pump and allow developing stable pressure.
- Clean all the filters as per the protocol.
- Open the bye-pass valve meant for sending water to the drip system to obtain desired pressure in the system.
- Traverse the field and check for leakage or damage to any components. Rectify the defects by replacing the parts, removing the folds and kinks in the laterals. Check the position of drippers and microtubes and keep them in the correct location if misplaced.
- Check the drippers for the uniform discharge of water. Open and clean the filters if required. Do not pull the emitter from laterals as it will lead to enlargement of hole and leakage.
- Remove the end stops and flush the laterals for about 1-2 minutes.
- Flush each sub main at the end of irrigation to remove the debris (Fig. 23). This is important since dirt is accumulated in mains and sub mains and if not flushed off, this may directly go to the dripper and clog the pores.

Fig. 23. Flushing the sub mainline (From Jain Irrigation systems)

6.4.2. Fortnightly maintenance

Clean the filters

Sand filter: Clean the sand filter by backwash, after adjusting the flow using the bypass valve such that sand does not come out (Fig. 24). Carefully stir the sand thoroughly while backwashing and also break the lumps if any (Fig. 25). Continue this until clean water flows out. If the sand is not filled up to the mark indicated, refilling with new sand may be required. Since the sand filter uses special crushed silica, ordinary sand will not serve the purpose.

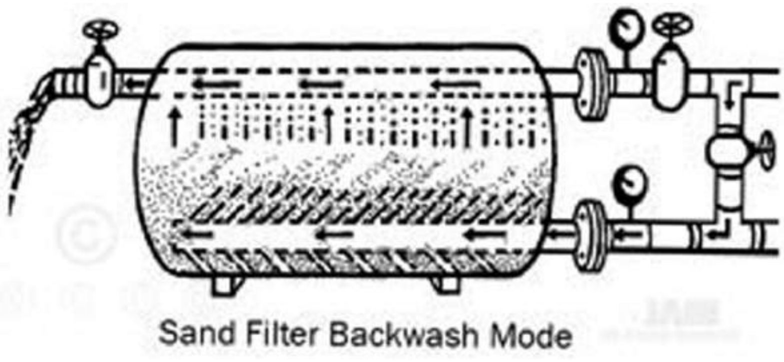

Fig. 24. Backwashing of sand filter (From Jain Irrigation systems)

Fig. 25. Cleaning of the sand filter by stirring the sand (From Jain Irrigation systems)

Screen filter: Remove the filter from the assembly, remove the rubber seals from both ends and clean with a light brush in running water.

Disc filter: Remove the filter from the assembly, remove the rubber seals and clean in running water.

6.4.3. Monthly maintenance

If required, perform the acid treatment to remove precipitated salts from drippers, microtubes and laterals. Perform chlorine treatment to remove algal growth, slime and bacterial growth.

1. Clogging of emitters is one of the major problems in drip irrigation systems. Take out the emitter/microtube from the lateral pipe and shake it or blow it to remove the trapped dirt. Openable types of emitters can be opened and clean with accessories such as a needle.
2. Leakage in the lateral, main and sub-mains: Cut the damaged part and connect it with joiner/connector.
3. Flush and clean the filters by opening and cleaning the same.
4. Flush the sub-mains and laterals by releasing the end caps.
5. Lubricate the movable screws and parts of the system both after using and when not using.

6.4.4. Chemigation

a) Acid treatment: Injection of Chlorine or acid to the drip irrigation system is undertaken to prevent the clogging of various components of drip system caused by the growth of bacterial slime, algae, chemical precipitation of iron and dissolved salts. The lines can be cleaned with the commercial grade hydrochloric acid, phosphoric acid or sulphuric acid at a concentration of 33-38%. Before passing the acid, it is recommended to flow the water through the system for 15 minutes. When the treatment is completed, allow the water flow to remove the residues of acid. It is advocated to chemigate during the middle of the irrigation cycle.

Rate of injection, litres/hour = [quantity of chemical compound, kg/ha x irrigation area, ha]÷[concentration of chemical in the solution, kg/lit x chemigation time, hours x irrigation duration, hours].

While chemigation, it is important to use specialised equipment to protect the user and water source. A safety valve/one-way valve can be used to avoid the contamination of water source by backflow of chemicals towards the water source. Also, an air relief valve needs to be installed between the irrigation pump and safety valve.

User tips for acid treatment: Apply hydrochloric acid till the water at lateral point get a pH of 4.0. and close the system and leave for 24 hours. Next day flush the system after opening the valves and blocks.

b) Chloration/Chlorination: Chlorination is performed to control the growth of bacterial slime and algae in the drip system. Sodium hypochlorite (NaOCl), Calcium Hypochlorite [$Ca(OCl)_2$] and gaseous chlorine (Cl_2 gas) are the commercial sources of chlorine. Sodium hypochlorite is safer and more popular and avoids the risk of calcium precipitation. Injection of chlorine to be done before filters to increase the filtration efficiency. The recommended rate of chlorine is 1-2 ppm for 30 to 45 minutes to prevent the growth of bacteria and algae and 10-20 ppm for 60 minutes to eliminate the already developed algae and bacteria. To dissolve the organic matter and calcium precipitated in the drip lines, inject chlorine at a concentration of 100 to 500 ppm and close the system and leave for 24 hours to clean the entire system. Chlorine at this level can be toxic to crops and need to be careful in following this practice. The chlorine being a biocide can cause damage to the young trees.

Chlorine injection rate, Litre per hour = [0.006 x system flow rate, litres per minute x desired chlorine concentration in water in ppm] ÷ strength of sodium hypochlorite in %.

- Continuous injection of chlorine should be used if the irrigation water has high levels of algae and bacteria. The recommended level of free chlorine is 1 to 2 ppm at the end of the irrigation system. It is important to check the concentration at the end of the lateral line since chlorine is consumed when it reacts with organic constituents and any iron and manganese in the water.
- Periodic (e.g. once per month) injections at a higher chlorine concentration rate (10 to 20 ppm) for 2 hours or more may be appropriate where algae and bacterial slimes are less of a problem. The frequency of injection depends on the potential organic clogging.
- Super-chlorination (injecting chlorine at high concentrations) is recommended for reclaiming drip irrigation systems clogged by algae and bacterial slimes.

Super-chlorination requires special care to avoid damage to plants and irrigation equipment.

Tips in chlorination: Chlorination helps to remove algae, bacteria and iron precipitates. Dissolve bleaching powder and inject to the drip system and close the system and leave for 24 hours. Next day flush the system after opening the valves and blocks.

c) Copper sulphate: To avoid the algal growth, apply copper sulphate at the rate of 0.05 to 2 mg per litre in the tank of the filter unit. If needed repeat it once in 15 days, however, adequate care must be exercised.

6.4.5. Important tips

Irrigation should be started only after flowering and stopped before starting the harvest.

The use of elbow and bends should be minimised in mainline and sub mainline to reduce pressure loss.

A drip system is best suitable in medium textured soils. And it is not very much ideal for clayey or gravelly soils.

Undissolved fertilisers may clog the drip system and should be subjected to filtration before injecting into the drip irrigation system.

Chlorine and acid treatment should not be combined.

The maximum chlorine concentration should not exceed 20 ppm. The chlorination should be undertaken at periodic intervals as needed and it should be invariably carried out at the end of the crop season and prior to the first use in next season.

Too high or low water pressure: In case of too high water pressure, fitting may drop off and the drippers may squirt water. The high pressure can be adjusted with the help of pressure regulators. In the case of low-pressure system, the water flow will be inadequate and inconsistent. Special arrangements such as overhead tanks or high capacity pumps may be required to solve the problem.

6.4.6. Care during the rainy season

Before the onset of the rainy season, backwash by flushing the system after removing the end cap of the lateral pipes. Replace the end cap of lateral pipes, roll the lateral pipes in circle and place near sub-main pipe at a high elevation.

Literature consulted

Anonymous. 2011. Methods manual - Soil testing in India. Department of Agriculture and Coopertaion, Government of India, New Delhi, p. 217.

Anonymous. 2015. Guidelines for use of micronutrients, soil ameliorants and integrated nutrient management practices in NFSM states. National Food Security Mission, Department of Agriculture and Cooperation, Government of India, New Delhi, p. 27.

Anonymous. 2013. Indian fertiliser scenario 2013. Department of fertilisers, Ministry of Chemicals and Fertilisers, Government of India. pp. 246.

DCCD. 2018. Area and production of cashew 2017-18, Directorate of Cashewnut and Cocoa Development, Kochi.

Goyal, M.R. 2012. Management of drip/trickle or micro irrigation. Apple Academic Press, New Jersey, USa. pp. 408.

http://jainpipe.com/Designtechnical/maintenance%20guidelines%20for%20filters.htm

https://www.floramax.com/nutrient-deficiencies/plant-deficiency-symptoms-flow-chart/ (Date accessed: 03-09-2018).

Mangalassery, S. and Nayak, M.G. 2019. Strategies for soil and water conservation and irrigation management in cashew. In: Eradasappa, E., Mog, B., Savadi, S. and Shamsudheen, M (Eds.), Training manual on Cashew production and post harvest technologies. ICAR-Directorate of Cashew Research, Puttur, India, pp. 51-64.

Mangalassery, S., 2018. Ad-hoc recommendations on nutrient deficiency management in cashew. ICAR-Directorate of Cashew Research, Puttur, India, p. 7.

Mangalassery, S., Rejani, R., Singh, V., Adiga, J.D., Kalaivanan, D., Rupa, T.R. and Philip, P.S. 2019. Impact of different irrigation regimes under varied planting density on growth, yield and economic return of cashew (*Anacardium occidentale* L.). *Irrigation Science* 37:483-494.

Nayak, M.G., Muralidhara, B.M. and Mangalassery, S. 2018. Innovative production technologies to enhance production and processing of cashew. In: Parameswaran, P.A., Jayalakshmi, V.S., Nikhil, V.M., Shine, K.K., Rohith, H.S., Lukose, V. and Gopinath, L. (Eds.), National Conference on Cashew. Directorate of Cashewnut and Cocoa Development, Kochi, India. Hotel Swosti Premium, Bhubaneswar, Odisha, India, pp. 28-37.

Poduval, M. and Yadukumar, N. 2011. Effect of different doses of fertilizers on different densities of cashew plantation. *Journal of Plantation Crops* 39, 35-40.

Rejani, R. and Yadukumar N. 2010. Soil and water conservation techniques in cashew grown along steep hill slopes. *Scientia Horticulturae* 126:371-378.

Rejani, R., Rupa, T.R. and Nayak, M.G. 2013. Suitability of cashew growing areas in India - an appraisal using GIS. *Journal of Agrometeorology* 15, 123-128.

Rupa, T.R. 2017. Nutrient and water management. In: Saroj PL (Ed.) Cashew: improvement, production and processing. *Astral International Pvt Ltd,* New Delhi, pp 233-252.

Salam, M.A. and Peter, K.V. 2009. Cashew-A monograph. *Studium Press (India) Pvt. Ltd.,* New Delhi, India. pp. 257.

Singh, D., Chhonkar, P.K. and Dwivedi, B.S. 2016. Manual on soil, plant and water analysis. *Westville Publishing House*, New Delhi.

Yadukumar, N. and Rejani, R. 2008. Soil and water management in cashew plantations. RCC Technical Bulletin No. 10. National Research Centre for Cashew. p. 12.

Yadukumar, N., Rejani, R. and Nandan, S.L. 2012. Effect of organic and inorganic nutrition in cashew. *Journal of Plantation Crops* 40, 1-8.

* * *