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Nutrient and Water Management

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1. Introduction

Cashew (*Anacardium occidentale* L.) is usually grown on a diverse range of soils, from the sandy seacoast to laterite hill slopes, pure sandy soils to sandy loam, laterite soil, deep loam and red latosols, but several of these soils have low effective cation exchange capacities and low exchangeable base status. Though, cashew is cultivated in numerous type of soils but it requires light textured and well drained soils rich in organic matter. Cashew tree is considered drought resistant to some extent and is generally grown as an unirrigated crop but the yield can be doubled, if irrigated. Low productivity is the main concern in cashew cultivation in India. Of several factors associated low productivity, poor soil fertility and low moisture availability during the fruiting season which normally coincides with the onset of dry season in the cashew growing areas are the major factors. There are 17 essential nutrients required for plant growth: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl) and nickel (Ni). Of these 17 nutrients, all except C, H and O are derived from the soil. When the soil cannot supply the level of nutrient required for adequate growth, supplemental fertilizer applications become essential. Owing to its extensive root system, cashew can draw nutrients from large volume of soil, and as a result it can perform reasonably well on poor soils where other crops fail to do so. In spite of cashew's ability to grow in poor soil, it does respond positively to improvements in soil fertility. Manures and fertilizers are the important inputs, account for 20-30 per cent of the total cost of production. Nitrogen is the mineral nutrient that cashew requires in the greatest amount. It has more influence on tree growth, production and quality of cashew than any other nutrient. Phosphorus is the second most limiting nutrient after N in the nutrition of cashew. It plays an indispensable role for many life processes such as photosynthesis, synthesis and breakdown of carbohydrates, and the transfer of energy within the plant. Potassium is the second largest nutrient next to N required by cashew. Potassium is necessary for several basic physiological functions like the formation of sugars and starch, synthesis of proteins, normal cell division and growth, and neutralization of organic acids.

In India, majority of the cashew growing regions are located on soils with poor fertility status. On other hand, nutrient mining has occurred in many cashew growing soils due to lack of affordable fertilizer/organic sources and where fewer or no biomass residues/leaf litter are recycled to the soils. Integrated nutrient management/site specific nutrient management practices involving combined application of chemical fertilizers, organic manures/green manuring and biofertilizers which constitute an efficient nutrient management strategy in cashew are crucial to improve soil quality for sustainable production. In cashew; flushing, flowering and fruit development stages are critical phases that decide the nut yield. Any form of stress, (biotic or abiotic) during these phases can decrease the yield substantially. Besides, canopy development; water availability strongly influences flowering and fruit set and can affect fruit drop, fruit size, nut yield and quality. Studies in India have shown that nut yield can be enhanced by providing protective irrigation with 200 L of water/tree once in 15 days from January to March during the summer season. Research results in Brazil and other countries have shown that irrigation could increase productivity by up to 300 per cent depending on the region. Drip irrigation is the most efficient irrigation system with savings of water between 40 to 60 per cent over other irrigation systems.

2. Nutrient Management in Cashew

Nutrient Removal

Theory of nutrient removal is one of the bases for integrated nutrient management. It has been estimated that annual removal of nutrients by a cashew tree of 30 years old was 2.847 kg N, 0.752 kg P and 1.265 kg K per tree (Mohapatra *et al.*, 1973). The nutrient requirement to produce one kg of cashew nut was 64.1 g N, 2.05 g P, 24.7 g K, 4.19 g Ca, 1.57 g S, 525.7 mg Fe, 63.6 mg Mn, 87.8 mg Zn and 26.5 mg Cu per tree (Beena *et al.*, 1995). The annual nutrient uptake required by cashew trees of 70 months of age in Australia were 2.1 kg N, 0.45 kg P, 1.32 kg K, 0.54 kg Ca and 0.57 kg Mg in order to maintain the tree structure (Richards, 1993). While, an eight-year old cashew tree removes 610 g N, 58 g P, 394 g K, 52 g Ca, 39 g Mg, 34 g S, 2.12 g Fe, 343 mg Mn, 390 mg Zn and 130 mg Cu in Australia (Grundon, 2001). Nutrient budgeting and balance studies in six-year old cashew plants under high density planting system (625 trees/ha) indicated a negative N, P and K balance of 113, 38 and 92 kg/ha in control plot where no fertilizer was applied. A strong positive N balance ranged from 137 to 251, P balance from 34 to 75 and K balance from 89 to 164 kg/ha/year was obtained in trees with two-thirds and full dose (750 g N and 150 g each of P_2O_5 and K_2O per tree/year) of fertilizer applications, respectively. While one third dose of fertilizer application resulted in a positive N, P and K balance of 40, 19 and 40 kg/ha/year (Yadukumar *et al.*, 2009). The constant removal of produce without or with inadequate replenishment of plant nutrients cause a steady decline of soil fertility. This mining of plant nutrients leads to severe deterioration of soil health. However, application of imbalanced and/or excessive nutrients led to declining nutrient use efficiency making fertilizer consumption uneconomical and producing adverse effects on soil and atmosphere.

Nutritional Management in Nursery

In cashew, initial growth of seedlings depends upon the nutrient reserve of cotyledon. Ximenes, (1995) reported that the macronutrients contained in the cotyledons can provide around 54 per cent of N, 45 per cent of P, 17 per cent of K, 1 per cent of Ca, 16 per cent of Mg and 36 per cent of S necessary for seedling development for up to 75 days after planting. The large size cashew nut (8 to 12 g) gave initial seedling growth advantage over that of small sized nuts (6 g) only at the juvenile stage but as the plants age advances the influence fizzles out (Ibiremo *et al.*, 2012). It has been reported that biofertilizers (*Azospirillum*, *Azotobacter* and VAM) increased the germination percentage of nuts, plant growth, number of graftable seedlings and reduced the incidence of fungal diseases in the nursery (Kumar *et al.*, 1998; Ramesh *et al.*, 1999; Sinish *et al.*, 2005). Inoculation of *Azotobacter* resulted in higher root growth (Oblisami *et al.*,1985) and yield (Singh, 1997) of cashew. Cashew has been described as a host plant for arbuscular mycorrhizal (AM) fungi (Sivaprasad *et al.*, 1992). Mycorrhizae have also been shown to help increase the resistance of plant root systems to soil-borne diseases (Perrin, 1990). Additionally, plants colonized by mycorrhizal fungi have been shown to survive better than uncolonized plants under suboptimal growing conditions and in marginal soils (Lioi and Giovannetti, 1987). VAM (25 g/bag) is helpful for better graft uptake at the time of grafting (Sridhar *et al.*, 1990). It has been demonstrated that inoculation of cashew with mycorrhizal inoculum had higher concentrations of K in both leaves and roots (Haugen and Smith, 1993). Among VAM, *Acaulospora laevis* and *Gigaspora mosseae* are better symbionts for inoculating cashew (Lakshmipathy, 2000). While Ananthakrishnan *et al.* (2004) reported, among VAM, *Glomus fasciculatum* is superior in terms of increased shoot length, internode number, number of leaves, stem diameter, root length and root number under nursery conditions.

A fertilizer dose of 150:20:100 (ppm) N:P:K to rootstocks and grafts of cashew at a rate of 100 ml/plant/week resulted in higher plant height, stem girth and number of leaves (Manjunatha, 2001). Addition of cocoa pod husk at 3 per cent by volume as substrate to soil is effective for raising cashew seedling in the nursery as it enhanced growth of cashew seedlings (Agele and Agbona, 2008).They also observed that cocoa pod husk improves the soil pH, organic carbon, N, K, Na and Ca contents of the soil besides increasing the contents of ash, N, K and Na in the cashew leaves. Diva Correia *et al.* (2003) evaluated the use of mature and immature coir dust for preparation of substrates for grafted dwarf cashew seedlings and reported that coir dust either from mature or immature fruit was suitable for seedlings growth, being able to replace the low humid glei soil at 20 per cent.

Nutritional Management in Cashew Plantations

Nitrogen and P were most important nutrients during the pre-bearing stage, but at the bearing stage, K together with N is also important. The response of cashew to applied N is tremendous and the same is observed universally. Increase in cashew yield due to N application was reported by several workers (Lefebvre, 1973; Reddy *et al.*, 1982; Rao *et al.*, 1984; Veeraraghavan *et al.*, 1985 and Ghosh, 1988). Ghosh (1990) reported that number of nuts/plant and nut weight was the highest at 600 g N/tree/year but Latha *et al.* (1994) obtained response to N up to 1000 g/tree. Urea is the most commonly used nitrogenous fertilizer in India. In Nigeria, urea and sulphate of ammonia are generally used. Falade (1984) reported that sulphate of ammonia was superior to urea particularly when medium or high doses of N were applied to cashew. Whereas, contradictory reports were observed regarding the response of cashew to P fertilizer. Rao *et al.* (1984) observed no response to P application in sandy loam soils. Also, Veeraraghavan *et al.* (1985) reported no effect of P on cashew in laterite soils of Madakkathara. It was observed that the main effect of P to increase the yield was limited to a dose of 25 kg/ha, but when applied with N fertilizer, P application increased yield up to a dose of 75 kg/ha (Sawke *et al.*, 1985). However, Kumar (1985) reported positive influence of P on nut yield. Richards (1993) reported that soil P is a major limiting nutrient in P deficient soils of Australia and P application increased the nut number and nut yield. Of phosphatic fertilizers for use in acid soils in India, the slow release and more efficient ground Mussoorie (rock) phosphate is popular. Application of K increased the production of cashew particularly in the presence of N (Lefebvre, 1973). Significant positive effects of K on growth and yield of cashew were reported by Ghosh (1988) and Ghosh (1990). While Veeraraghavan *et al.* (1985) reported no positive effect of K application in cashew. Kumar (1985) obtained linear response for K up to 150 g K_2O/ tree. Phosphorus and K application at higher level improved the nut yield (Sawke, 1980). Increased nut weight and nut yield due to application of higher levels of N, P and K was reported by Ghosh and Bose (1986), Harishu Kumar and Sreedharan (1986), Ghosh (1990) and Kumar *et al.* (1995).

It is essential that level of micronutrients in soil and plant should be optimum for growth and development, since the micronutrients need is site specific. Foliar feeding is often the most effective and economical way to correct micronutrient deficiencies in horticultural crops. Foliar application of nutrients normally reduces the loss through adsorption, leaching and other processes associated with soil application. Deficiencies of Fe, Mn, Zn, Cu, B and Mo can be corrected by foliar sprays of 0.5-1.0 per cent ferrous sulphate, 0.5-1.0 per cent manganese sulphate, 0.5 per cent zinc sulphate, 0.1 per cent copper sulphate, 0.1 per cent solubor and 0.1 per cent Mo salts, respectively to cashew at the emergence of the flush, panicle initiation and fruit set stages.

Application of fertilizers, dosage and the time and its schedule under different agro-climatic zones has been standardized (Veeraraghavan *et al.*, 1985; Harishu

Kumar and Sreedharan, 1986; Grundon, 2001; Salam *et al.*, 2008; Yadukumar *et al.*, 2009). A summary of the recommended dose for the macronutrients for major cashew producing states is presented in Table 13.1. Application of farmyard manure (FYM) at a rate of 10-15 kg/plant in combination with N, P and K fertilizer is effective in enhancing the nutrient use efficiency. The requirement of nutrient dose may vary from location to location based on the initial fertility status of soil. The magnitude of yield response to fertilizer dose may vary with respect to tree canopy, initial soil fertility status, nature of soil, other management practices etc. Site specific nutrient management offers the most appropriate option to deal with the spatial variation in soil fertility using variable fertilizer rates as per soil test values.

Table 13.1: Recommended Dose of Fertilizers to Cashew

State	*Nutrient Dose for Mature Cashew Plantations (5^{th} year of planting onwards) (g/tree/year)*		
	N	*P_2O_5*	*K_2O*
Kerala	500–750	125–325	125–750
Karnataka	500–500	250–125	250–125
Tamil Nadu	500	200	300
Andhra Pradesh	500–1000	125–125	125–125
Maharashtra	1000	250	250
Odisha	500	250	250
West Bengal	1000	250	250

Source: ICAR-DCR, Puttur and AICRP-Cashew Centres.

Integrated use of organic manures, inorganic fertilizers and biofertilizers assumes great importance for sustainable cashew production and maintaining soil health. The organic manures and biofertilizers not only supply essential plant nutrients, but also improve the soil physical, chemical and biological health. Inoculants of *Azotobacter* and *Azospirillum* either sole or in combination have been shown to improve N nutrition of plants through biological N_2 fixation and also secretion of some growth promoting substances which affect the growth, nutrition and microbial activity in the rhizosphere (Zayed, 1999). The phosphate solubilizing microorganisms (*Pseudomonas*) play an important role in conversion of unavailable forms of P into available P forms through secretion of organic acids and enzymes. Arbuscular mycorrhizal fungi (AMF), on the other hand are ubiquitous in soils throughout the world and play an important role in affecting the plant growth through mobilization of nutrients. Often, FYM is limited in supply, suggesting that green manure may be a more feasible substitute for fertilizer N. Green manuring maintains and improves soil structure by addition of organic matter, minimize P, K fixation in soils, produces humus, which enhances the utilization of fertilizer nutrients by plants and helps in reducing leaching losses by enhancing water retention ability of soil. Growing green manuring crops like *glyricidia*, sesbania, sunhemp and cover crops between two rows of cashew resulted in the nutrient addition of 186 kg N, 23.6 kg P_2O_5 and 126.2 kg K_2O through *glyricidia* and 141 kg N, 17.9 kg P_2O_5 and 162.3 kg K_2O/ha through sesbania (Yadukumar *et al.*, 2008).

Method of Fertilizer Application

Cashew trees are surface feeders with about 50 per cent of the root activity being confined to the top 15 cm of the soil and about 72 per cent of root activity was found within a 2 m radius from the tree trunk (Wahid *et al.*, 1993). It has been suggested to apply fertilizers within a radius of 2 m from the main stem for efficient utilization of the applied nutrients. During the 1st, 2nd, 3rd, 4th and 5th year of planting 1/5th, 2/5th, 3/5th, 4/5th and 5th year onwards full quantity is to be applied. George *et al.* (1984) reported application of N, P and K fertilizers in two circular trenches (1.5 and 3 m from the trunk) for sandy soils, a single trench method (25 cm wide and 15 cm deep circular trench at 3 m from the trunk) for sloping ground, and the band method (in a circular band 1.5-3 m from the trunk + soil incorporation) for flat ground are best suited. The root activity of cashew in relation to phenological phases studied by Beena *et al.* (1995) employing ^{32}P soil injection technique reported that flushing and early flowering phase (September to December) is the most appropriate time for fertilizer application in cashew orchard. The annual dose of fertilizers to cashew are to be applied in two split doses, the first split dose at the onset of the pre-monsoon period and the second split dose during the post-monsoon period when the soil moisture condition is at its optimum; if only one application is given, it should be in the post-monsoon period when enough moisture is available.

3. Water Management in Cashew

Water Requirement, Time and Method of Irrigation

Irrigation scheduling, knowing how much water to apply and when, has a direct influence on tree health as well as nut yield and quality. Right irrigation scheduling requires an understanding of how much water can be held in the plant root zone. In order to maintain the optimum level of water in crop and to schedule irrigation, an estimation of water requirement is prerequisite. Water requirement of a crop depends on crop, soil type and atmospheric demand for the water. Generally, crop water requirement is defined as the depth of water needed to meet the water loss through evapotranspiration (ET_{crop}) as a healthy crop under non-restricting soil conditions and attaining full production potential under the given growing environment. Fresh grafts when planted require sufficient soil moisture for initial establishment, hence cashew is planted during monsoon season. Whenever there is drought situation after planting they need protective irrigation. The irrigation through pitcher (hold pots) is recommended in dry land situations. Under drought situation, irrigation is one of the most important factors in establishing the newly planted grafts well. Care must be taken to keep the soil moist but not waterlogged. The root ball of a newly planted graft must be kept moist to supply the plant with water until its roots grow into the soil. Newly planted grafts need to be watered every three to seven days, depending on the soil type and weather conditions. Because of their deep taproot system, established cashew trees can survive the dry season without irrigation, but premature nut drop is a common problem. While not essential, irrigation could prove to be a major benefit to production, largely by preventing nut drop. Irrigation during critical phases of established cashew trees improves nut yield.

Field experiments conducted at ICAR-Directorate of Cashew Research (ICAR-DCR), Puttur on fertigation in cashew indicated that under normal density planting system (7 m x 7 m), the effective canopy coverage per tree is 12.56 m^2. The quantity of water requirement calculated based on the effective canopy area was 12.56 L/tree/day from December to January (Daily open pan water evaporation is 5 mm) and 20 L/tree/day from February to March (Daily open pan water evaporation is 6.5 mm) to meet 20 per cent of the cumulative pan evaporation (CPE). Similarly, for 40 per cent CPE and 60 per cent CPE, the water requirement was 24 L/tree/day and 38 L/tree/day from December to January and 36 L/tree/day and 58 L/tree/day from February to March, respectively. In order to meet 20 per cent CPE, four drippers of 2 L/hour discharge rate can be fitted at two equidistant points 1 m away from the base of the tree. Similarly, to meet 40 per cent and 60 per cent CPE, four drippers and six drippers of 4 L/h discharge rate can be fixed. Drip irrigation can be given for 1 h and 30 minutes during December-January and 2 h during February-March (Yadukumar and Rejani, 2008).

Estimating Water Requirement for Cashew

To meet 20 per cent CPE

Age of the tree: 5 years

Canopy spread: 4 m, Canopy spread = canopy diameter = mean of EW and NS length

Canopy area = πr^2 where r = radius of the canopy.

If the radius is 2 m, the total area covered by individual tree canopy is 3.14(π) x 2^2 = 12.56 m^2 (Ground coverage by canopy)

Daily CPE = 5 mm, 20 per cent of CPE = 1 mm, Therefore, quantity of water to be given to meet 1 mm of water in 12.56 m^2 area = 12.56 x 1/1000=0.01256 cubic M, 1cubic M =1000 L. Therefore, 0.01256 cubic M =12.56 L/tree/day. The water requirement of cashew can be calculated depending upon the canopy coverage and daily water evaporation.

Mishra *et al.* (2008) estimated the water requirement of cashew on daily basis for all months of a particular year and the net average seasonal water requirement of crop as per their estimate was 997 mm. Water requirement can be calculated based on evaporation rate in the given area and crop factor (K_c). For cashew, K_c varies from about 0.8 at peak flowering to 1.1 at peak nut set. Cashew needs irrigation from the onset of flowering to late nut set. Supplementary irrigation for younger plants may be required during drier parts of the year and to assist with fertilizer applications. Trees irrigated with sprinklers will need about 500 L/tree/week and 50 per cent of the water requirement can be saved with drip irrigation. Irrigation should be stopped before starting harvest, to avoid nut germination on the ground (Website: www.deedi.qld.gov.au). The optimum temperature for CO_2 assimilation is in the range 25–35°C. Progressive closure of the stomata occurs at saturation deficits of the air >1.5 kPa. In the field, differences in rates of gas exchange between irrigated and unirrigated cashew trees only become apparent three or four months after the end of the rains. The stomata playing an important role in maintaining a favourable leaf water status in dry conditions. Sap flow measurements indicate transpiration rates of 20–28 L d^{-1} $tree^{-1}$. Irrigation can be beneficial during the period from flowering to the start of harvest, but reliable estimates of water productivity have yet to be established. The best/only estimate is 0.26 kg (nut in shell) m^{-3} (irrigation water) (Carr, 2014).

The ability of unirrigated cashew trees to draw moisture below 1.8 m depth was apparent from the experimental results as such trees gave virtually zero water use over recorded depth at peak nut set, yet they were able to give yield ranging from 20 to 70 per cent of the highest irrigated yield (Richards, 1993). He further stated that this poses the question of the long term irrigation requirements of well-established cashew trees. Richards (1993) raised questions whether such mature trees with presumably dry root system require wet season fertilizer application only as in the case of no irrigation and or require irrigation reduced to a critical period only in order to produce economic yields. Schaper (1991) reported that leaf gas exchange was lower and water potential higher in leaves of unirrigated cashew trees near peak flowering compared to irrigated trees, but that both declined after flowering commenced compared with pre-flowering, wet season levels. Further, he reported that stomatal regulation in cashew appears to prevent leaves from losing water faster than their roots can replace it by absorption. Non production of new shoots in March, April and May in unirrigated tree was the mechanism to withstand stress situations whereas in irrigated trees new shoots were produced in March, April and May but then these shoots never flowered during that season. Advantage of these new shoots is mostly for the better production of flushing shoots after the rainy season (October onwards) thereby total canopy area increased and total flowering laterals increased/tree considerably.

In a study conducted in Australia by Schaper *et al.* (1996) indicated that the plant could be irrigated only between flowering and harvest without decreasing yield compared to irrigating during the entire drought period. This saves much water. The water needs of the plant vary with climate, the plant's foliar area, the growth phase of the plantation and with the irrigation method used. During periods of high evapotranspiration, 5 L of water/day are recommended for each square meter of soil surface shaded by the plant crown or area wet by the emitters (Table 13.2). The frequency of irrigation depends on the water retention capacity of the soil and should vary between two and four days, for sandy and clayey soils, respectively. With drip irrigation, the volumes of water recommended in Table 13.2 may be reduced by about 15 per cent. The number of drippers per plant should increase gradually, according to the age and stature of the plant, from one dripper during the first year to up to four, six or eight to mature plant in clayey, medium textured and sandy soils, respectively. Richards (1993) reported that water requirement by five-year-old cashew tree growing in sandy soil and under high evaporative demand is about 400 to 500 L/tree/week which equated about 30 L/m^2 of canopy area.

Table 13.2: Average Values of Crown Projection Areas, Percentage of Soil Covered by the Plant and Volume of Water to be Applied in Irrigation as a Function of Plant Age

Year of Crop	*Crown Projection Area* m^2	*Soil Covering per cent* [1]	*Volume of Water L/plant/d* [2]
1st	1	2	5
2nd	5	10	25
3rd	15	30	70
4th	25	50	120
5th +	30	60	145

1. Assuming the spacing between plants is 7 m x 7 m

2. If the area wetted by the nozzle is greater than the crown projection, the volume of water to be applied should be chosen as a function of the wetted area.

Studies on effect of black polyethylene mulch and supplemental irrigation (60 L of irrigation water/tree given manually at 15 days interval from the emergence of panicles and 6 to 8 total irrigations during each season) on fruit retention of cashew nut revealed that polyethylene mulch + irrigation treatment had maximum fruit retention of 66.15 per cent followed by irrigation alone (58.04 per cent) and polyetheylene mulch alone (52.83 per cent). The correspondence fruit retention in control (no polyethylene mulch and no irrigation) was 44.98 per cent (Nawale *et al.*, 1985). Studies on the effect of supplementary irrigation on fruit retention and nut yield at NRC-Cashew (Presently ICAR-DCR) on cashew trees of 13 years old with four different treatments, *viz.*, fortnightly irrigation @ 200 L/tree from (1) November to January; (2) January to March; (3) November to March; and (4) Control (No irrigation) revealed that there has been increase in fruit retention in irrigated plots as compared to control (Table 13.3). Irrigating cashew during November-March (10 irrigations) was significantly superior to other treatments of irrigations: November - January and January - March (5 irrigations each). Analysis of two years pooled data also showed similar results (Table 13.4). Irrigations has increased fruit retention (nut retention) which ultimately increased the yield (Yadukumar and Mandal, 1994).

Drip irrigation or more broadly known as micro-irrigation is mainly suited for orchard and plantation crops where it saves 30-70 per cent irrigation water and increase yield by 25-80 per cent. It is recommended to use micro-irrigation (spray or drip), because of certain advantages like decreased incidence of leaf sickness and weeds, water saving by decreasing losses by evaporation and greater efficiency of water use. Micro-irrigation can also be adapted to different soil and topographies; there is a saving in labour costs and efficient application of fertilizers via irrigation water (fertigation). The initial cost of a system of micro-irrigation for cashew varies from R$ 3,000 to R$ 4,500 (US$ 1,000 to US$ 1,500) per hectare. Where spraying is used it is recommended to have one jet per plant, with a nominal flow of 30 to 70 L/h and wetting diameter of 3.5 to 5.0 m. In dripping, a minimum of four drippers per plant ought to be used per mature plant in clayey soils, and up to eight drippers per plant in sandy soils. To choose between spray and dripping as a system of irrigation, the water availability (quantity and quality) should be considered. In dripping there is a greater savings in water and energy, because the loss of water by evaporation from the soil surface is less and the system operates at a lower pressure. On the other hand, the risk of emitter blocking is greater than with spray irrigation, thus better filtering, especially when surface water with a lot of organic matter is used. Dripping also offers the advantage of not wetting the fruits that fall onto the ground, allowing less frequent collecting where the primary product required is the nut (www.ipipotash.org).

Table 13.3: Fruit Retention as Affected by Irrigation

Treatments	*Fruit Set (Mean 5 panicles)*	*No. of Fruits Harvested*	*Fruit Retention (Per cent)*
(a) Irrigation once in 15 days @ 200 L/tree from			
November-January	27	9	33.0
January-March	16	6	37.5
November- March	25	11	44.0
(b) Control	13	4	30.4

Table 13.4: Cashew Nut Yield as Affected by Irrigation

Treatments	*Nut Yield (kg/tree)*		
	1987	*1988*	*Mean of Two Years*
(a) Irrigation once in 15 days @ 200 L/tree from			
November-January	5.33	4.53	4.93
January-March	5.82	4.93	5.37
November- March	5.33	7.32	6.25
(b) Control	2.91	3.54	3.23
CD (p=0.05)	NS	1.47	1.64

NS: Non significant.

The most serious problem in trickle irrigation is clogging of emitters or applicators. Recommendations and guidelines need to be followed for preventive maintenance which include water filtration, chemical treatment, pipeline flushing, and field inspection. A suitable type, size, and capacity of a filtration unit is required. Chemical treatment should be considered in terms of theory and field research on the reclamation and prevention of emitter clogging. Proper procedures for the flushing and field inspection of trickle irrigation systems are also essential (Bucks *et al.*, 1979). Salts in soil or water reduce water availability to the crop to such an extent that yield is affected. No specific quality standards apply to cashew irrigation, however, the general water quality standards can be used. Electrical conductivity of irrigation water should not exceed 0.8 dS/m and total dissolved ions should be less than 600 ppm.

In young cashew, application of 30 L of water/tree at 15 days interval increased the nut yield by 393 per cent when compared with unirrigated plants in West Bengal

(Ghosh, 1995). Drip irrigation @ 43 mm/week from April to October increased nut yield by 20 per cent in Australia (Schaper *et al.*, 1996). The response to irrigation varied among cashew genotypes. Irrigation increased nut yield of dwarf cashew clones CCP-76 and CCP-09. The highest nut yield was obtained with cashew clone CCP-09 irrigated when accumulated pan evaporation reached 10 mm. Cashew alternated years of high nut yield with years of low nut yield, even when irrigation was applied. Irrigation did not influence nut weight of clones CCP-76 and CCP-09 (Oliveira *et al.*, 2006). Mishra *et al.* (2008) evaluated the economic feasibility of drip irrigation with black Linear Density Poly Ethylene (LDPE) mulch on the loamy soil in coastal Odisha and reported that the drip irrigation is economical and cost effective as compared with conventional basin irrigation. It was shown that an increase of 108 per cent in nut yield and 122 per cent in net seasonal income obtained with 80 per cent irrigation requirement through drip irrigation + black LDPE mulch with the highest benefit cost ratio of 3:1 over the conventional ring basin irrigation. Mulch alone could increase the yield by 16 per cent even in the absence of drip.

4. Response of Cashew to Supplementary Irrigation during Flushing and Flowering Phases

Experiments conducted at All India coordinated Research Project on Cashew (AICRP-Cashew), Vengurla (Maharashtra) indicated that the growth and yield attributing characters of cashew variety Vengurla-7 did not vary significantly among irrigation levels using drip. The fruit set/m^2 was the highest in irrigation @ 60 per cent CPE. Mean No. of nut/panicle was the highest in irrigation @ 80 per cent CPE. While cumulative nut yield for nine harvests was maximum in irrigation @ 40 per cent CPE (Tables 13.5 and 13.6).

Experiments conducted at AICRP-Cashew, Vridhachalam (Tamil Nadu) revealed that irrigating the cashew plants variety VRI-3 at 80 per cent CPE enhanced plant height, trunk girth, canopy spread and canopy surface area. The flowering was early in trees receiving irrigation at 80 per cent CPE (Table 13.7).

Experimental results of AICRP-Cashew, Chintamani (Karnataka) revealed that, among different levels of irrigation, irrigating the crop at 80 per cent CPE resulted in significantly the highest plant height and stem girth while there was no significant difference in canopy spread. Maximum E-W and N-S canopy spread was obtained in irrigation at 80 per cent CPE. Nut yield varied significantly among the irrigation levels. The highest nut yield, nut weight, shelling per cent and cumulative yield of 5 harvests were obtained in irrigation at 80 per cent CPE (Table 13.8).

5. Irrigation and Fertilizer Effects on Cashew

The irrigation and fertilizer experiments in cashew conducted in Northern Territory of Australia indicated substantial reduction in yield, tree size and yield efficiency associated with absence of fertilizers and irrigation inputs (Richards, 1993). Application of fertilizer increased yield significantly compared to that of unirrigated and or unfertilized trees. He has reported that rate of irrigation had limited impact on yield, size and efficiency in similar size trees producing at high, medium and low rates of irrigations (600, 490, 290 L/tree once in a week) within irrigation and

Table 13.5: Effect of Drip Irrigation on Growth and Yield Attributes of Cashew at Vengurla (Maharashtra)

Irrigation Levels	*Mean Plant Height (m)*	*Mean Stem Girth (cm)*	*Mean Canopy Spread (m)*	*Mean Canopy Area (m^2)*	*Mean No. of Laterals/m^2*	*Mean No. of Flower Panicle/m^2*
No irrigation	7.30	86.24	7.64	46.84	31.90	15.97
Irrigation at 20 per cent CPE	7.11	91.08	8.27	54.44	31.60	17.23
Irrigation at 40 per cent CPE	7.47	90.83	8.34	55.15	30.30	16.62
Irrigation at 60 per cent CPE	7.41	85.41	7.83	48.72	32.0	17.95
Irrigation at 80 per cent CPE	7.14	91.91	8.03	51.49	28.93	16.80
SEm±	1.19	2.96	0.34	4.17	1.11	0.42
CD (p = 0.05)	NS	NS	NS	NS	NS	NS

NS = Non significant.

Table 13.6: Effect of Drip Irrigation on Yield Attributes and Yield of Cashew at Vengurla (Maharashtra)

Irrigation Levels	*Mean Flower Duration (days)*	*Mean Fruit Set/m^2*	*Mean No. of Nut Panicles*	*Mean Apple Weight (g)*	*Mean Nut Weight (g)*	*Cumulative Yield for 9th Harvest (kg/tree)*
No irrigation	102	69.07	14.77	66.00	9.75	26.81
Irrigation at 20 per cent CPE	105	79.37	15.20	67.75	9.17	28.30
Irrigation at 40 per cent CPE	108	76.55	14.67	70.00	9.22	29.84
Irrigation at 60 per cent CPE	110	89.87	15.55	67.75	9.10	26.46
Irrigation at 80 per cent CPE	101	84.65	16.65	69.00	9.00	28.74
SEm±	5.45	4.50	1.08	2.09	0.20	–
CD (p = 0.05)	NS	NS	NS	NS	NS	–

NS = Non significant.

Table 13.7: Effect of Drip Irrigation on Growth of Cashew at Vridhachalam (Tamil Nadu)

Irrigation Levels	*Plant Height (m)*	*Trunk Girth (cm)*	*Mean Canopy Diameter (m)*	*Canopy Height (m)*	*Canopy Surface Area (m^2)*
No irrigation	3.42	40.5	2.46	2.22	9.65
Irrigation at 20 per cent CPE	3.98	42.2	[illegible]	[illegible]	[illegible]

Irrigation at 80 per cent CPE	101	84.65	16.65	69.00	9.00	78.74
SEm±	5.45	4.50	1.08	2.09	0.20	–
CD (p = 0.05)	NS	NS	NS	NS	NS	–

NS = Non significant.

Table 13.7: Effect of Drip Irrigation on Growth of Cashew at Vridhachalam (Tamil Nadu)

Irrigation Levels	*Plant Height (m)*	*Trunk Girth (cm)*	*Mean Canopy Diameter (m)*	*Canopy Height (m)*	*Canopy Surface Area (m^2)*
No irrigation	3.42	40.5	2.46	2.22	9.65
Irrigation at 20 per cent CPE	3.98	42.2	2.82	2.76	14.50
Irrigation at 40 per cent CPE	4.12	44.0	3.44	3.02	18.68
Irrigation at 60 per cent CPE	4.56	45.8	3.92	3.34	23.86
Irrigation at 80 per cent CPE	4.91	52.2	4.60	3.70	32.49
CD (p = 0.05)	0.18	0.26	0.64	0.32	5.12

Table 13.8: Effect of Drip Irrigation on Growth and Yield of Cashew at Chintamani (Karnataka)

Irrigation Levels	*Plant Height (m)*	*Stem Girth (cm)*	*Nut Yield (kg/tree)*	*Cumulative Yield (kg/tree) of 5 Harvests*	*Nut Weight (g)*	*Shelling (Per cent)*
No irrigation	4.42	78.54	8.25	31.81	6.9	29.50
Irrigation at 20 per cent CPE	4.61	79.46	10.10	39.00	7.1	30.10
Irrigation at 40 per cent CPE	4.67	85.67	12.85	44.91	7.2	31.40
Irrigation at 60 per cent CPE	5.03	86.83	14.20	51.63	7.2	31.30
Irrigation at 80 per cent CPE	5.11	88.08	14.75	54.55	7.4	32.10
SEm±	0.10	0.94	0.94	–	–	–
CD (p = 0.05)	0.30	2.90	2.89	–	–	–

fertilizer frequency treatments. At medium and high level of irrigation the yield and kernel recovery increased significantly compared to low irrigation levels for trees applied after commencement of flowering. Further, it was reported that the combination of irrigation treatments and fertilizer frequency interacted to effect tree size with smallest tree canopy in the absence of fertilizer with or without irrigation. Kernel recovery was influenced by the combined effects of irrigation and fertilizer as post-flowering irrigation at low rates, unirrigated and unfertilized treatments, gave significantly lower recovery rates.

It has been documented that irrigation in the absence of adequate nutrition is wasteful (Richards, 1993). Irrigation and nutrient application together gave larger tree canopy, greater yield and improved efficiency although the phenology cycle was not affected. Irrigation at low rates was the most efficient in terms of water use efficiency but carries the risk of reduced yield and kernel recovery rate. Richards (1993) reported that duration and intensity of flowering for both irrigated and unirrigated tree from 1988 to 1990 in cashew showed similar patterns in each year. In 1990 the unirrigated trees gave significantly lower peak flower level than irrigated trees. The pattern of 1990 flowering was different from that of previous years and showed a delay in flowering at the beginning before recovery in the seventh week and a quicker decline in flowering after the peak was reached. He reported that in cashew significant variations in water use and Kc (Crop coefficient) values range from 0.45 to 1.0 depending upon the ground cover and size.

The highest nut yield (3.8 kg/tree) was obtained from trees provided with 80 per cent recommended dose of fertilizers as water soluble fertilizers through drip irrigation, compared to trees supplied with recommended dose of NPK through soil without drip irrigation (Kumar *et al.,* 1998). Latha and Salam (2001) found that in rainfed trees, application of N 500 g/tree/year produced 0.77 kg nuts/tree while trees applied with no N resulted in zero yield. In irrigated trees (40 L/tree/day), N application of 1.5 kg/tree/year resulted in an increase in yield by 54 per cent compared to rainfed trees. When the irrigation level was increased to 80 L/tree, the yield increased was 124 per cent. In studies on drip irrigation and graded levels of N, P and K on cashew productivity, irrigation through drip @ 80 L/tree once in 4 days and a fertilizer dose of 750 g N, 187.5 g P_2O_5 and 187.5 g K_2O/tree/year resulted in 10 fold higher total root production (119.30 kg/tree) and 34.34 per cent higher nut retention (70.7 per cent) over untreated trees (no irrigation and no fertilizer) (Yadukumar, 2001).

6. Fertigation

The application of fertilizers through the irrigation water (fertigation) has the advantages of increasing the efficiency of the fertilizers and reducing the costs of labour and machinery for its application. Fertigation allows the application of nutrients with greater frequency, without increasing the cost of the application, minimizing losses by volatilization and leaching and optimizing nutrient absorption by the roots. The nutrients most frequently applied in fertigation are those with greater mobility in the soil, like N and K (Oliveira *et al.,* 2003). To apply nutrients by fertigation, tanks of the solution, where the fertilizers are pre-diluted in water, and an injecting device are necessary. The types of injectors most utilized in fertigation are: injector pumps, venturi and differential pressure tanks. There are many advantages to fertigation: a) uniform application of nutrients; b) application of nutrients according to the needs of the plant and the rate of uptake; c) greater efficiency of nutrient use due to its mobility in the wetted zone of the soil where the root system is concentrated; d) savings on labour and agricultural equipment; e) reduction in soil compaction from the use of heavy equipment; f) ability to apply nutrients more frequently thus reducing nutrient losses (Santos,1997). Fertigation needs to be carefully managed to avoid soil acidification and salinization in the root zone. To avoid blocking the emitters the fertilizers used should be fully soluble in water and should not form precipitates, especially calcium and iron phosphates.

With fertigation, the quantity of nutrients (through fertilizers and organic manure) to be applied can be reduced to half the quantity of recommended nutrients. It has been reported that an increase of 100 per cent and 226 per cent in yield with the application of half of the recommended dose of N, P and K in inorganic form (Recommended dose: 500 g N, 125 g each of P_2O_5 and K_2O/tree/year) of nutrients through fertigation and balance half applied in organic form through castor cake as compared to the above dose applied through soil and irrigated separately and absolute control (without fertilizer, manure and irrigation), respectively indicating better nutrient use efficiency (Yadukumar and Rejani, 2008). Fertigation saved 50 per cent in the fertilizer requirement and doubled the cashew yield (Richards, 1993; Yadukumar and Mandal, 1994; Mishra *et al.*, 2008).

7. Drainage

In poorly drained soils, cashew plants exhibit poor growth with the resultant low productivity. In order to get optimum yield, a proper drainage in cashew orchards is essential. In fact, removal of excess water from the active root zone during rainy season facilitates favourable soil moisture conditions for the growth of plants. High water table and soil moisture content during critical periods of reproduction phase may also affect flowering of trees and subsequent productivity. The water table in the orchard should be below the active root zone *i.e.*, one to one and a half meters below the ground level. With shallow water tables, a salinity problem may also exist due to upward movement of water and salts from the ground water as the water evaporates from the soil or is used by the crop. Such a salinity problem is related to high water tables and the lack of drainage; it is only indirectly related to salts in the irrigation water.

Therefore, adequate drainage both surface and subsoil drainage is essential. Surface drainage removes excess surface water quickly during and after heavy rains. This is achieved by making beds unless the natural topography has a slope of at least 0.5 per cent. Beds may contain from 1 to 4 rows of trees. The height and slope of beds need only be enough to move surface water (0.5 per cent or more), assuming sufficient profile drainage. Surface water can be diverted into collection ditches by means of drop pipes. Water that soaks into the soil and thereby resulting in raising the water table should be removed by subsurface drainage. This may be done through the use of subsurface drains or open ditches. Both surface and subsoil drainage are required for water management in poorly drained soils in high rainfall areas. Proper drainage not only improves soil aeration but also prevents salt accumulation in soils. However, lands with poor drainage and high water table can also be utilized for cashew cultivation by planting on mounds.

8. Future Line of Work

- ☆ Need to develop site-specific nutrient management strategy which enables cashew growers to apply the right quantity of required nutrients at right time.
- ☆ Need to promote balanced, efficient and environmentally sound nutrient management system in cashew based cropping systems.
- ☆ Need to develop optimum concentrations and/or optimum ranges of nutrients useful for correct diagnosis and improvements of nutrient status of cashew plants.
- ☆ Development of models for predicting nutrient response in cashew.
- ☆ Need to standardize scheduling of irrigation to cashew based on plant water balance in consonance with soil and climate.
- ☆ Need to develop the water requirements of cashew under different planting systems and agro-climatic zones.

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