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Review on Foliar Application of Plant Nutrients on Castor

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Abstract: Castor is the main non-edible oilseeds crop of semiarid and arid regions of India and worldwide commercially grown in nearly more than 30 countries. Castor is a nutrient-demanding crop and responsive to higher nutrient application. Under irrigated conditions, removal of N, P, K and S kg per tonne of castor production was 30.3, 9.8, 15.6 and 3.1, respectively. Castor leaves are large, about 15-45 cm long, with long petioles. The number of leaves vary among different hybrids and growth stages. The number of leaves increases until harvesting of the first spike and then decreases subsequently. Stomata are found on both the surfaces of leaves (amphistomatic) and are almost equal in size. The principal type of stomata is paracytic type. The foliar fertilizers are also performed mostly by the transcuticular pores 'cuticles' as well as through stomata on foliage, which are open virtually all the time compared to stomata. Nutrient solution can stay for longer time on castor leaf, this feature makes castor leaf suitable for foliar application of nutrients. Castor leaves can absorb inorganic and organic nitrogen (urea, ammonium, nitrate and others) through stomata and cuticle openings. In the case of foliar application of phosphorus nutrient, it was found that phosphoric acid was more effective than mono potassium phosphate. Foliar application improves seed yield and quality of oil. Young leaves have been found to absorb nutrients more effectively than the old and mature ones. However, over dose of foliar plant nutrients like urea may cause leaf injury and frequent application of right fertilizer are needed to be used for obtaining maximum benefit of foliar fertilization.

Keywords: Castor, Foliar application, plant nutrients, *Ricinus communis,* spray

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1. Introduction

Castor (*Ricinus communis* L.) (commonly known as *Erand* in Hindi) is an important non-edible oilseed crop of the *Euphorbiaceae* family. The oil content in castor seed varies from 45 % to 51 % in cultivated varieties or hybrids, whereas the by-product of oil extraction, Castor de-oiled cake (DOC) or meal, also serves primarily as an organic fertilizer (4.5 % N). The castor is not new to Indians as the medicinal benefit of castor was known to the Indians since ancient time as it was evidenced in the ancient Indian books like *Susrut Samhita and Charak Samhita,* written more than 2000 years back. The presence of a unique fatty acid *i.e.* ricinoleic acid (12-hydroxy, 9-octadecenoic acid) makes castor oil suitable for many industrial usages (Shah *et al.* 2017).

1.1. Global and Indian castor cultivation scenario

The commercial cultivation of castor is carried out in over 30 countries especially in arid and semi-arid regions of the world. India, Mozambique and Brazil are the major castor growing countries and account for about 93 per cent of the world's total castor production. Worldwide castor is cultivated on 1.30 m ha with production of 1.88 m tonnes, with average productivity of 1438 kg/ha. India is the castor leader in the world with 70.3 percent of area coverage and 87.5 percent of production followed by Mozambique (14.9 percent area coverage and 3.9 percent production). Brazil ranked third with 3.5 per cent of total area and 1.9 per cent of total global castor production (FAOSTAT, 2023). The semi-arid and arid region of western India (Gujarat and Rajasthan) are the major castor producing region of India. In southern India, castor is cultivated in parts of Andhra Pradesh, Telangana, Karnataka and Tamil Nadu. In India, Gujarat has the maximum area under castor production (80.3 %); and accounts for more than 85% of the total castor seeds production (SEA, 2023).

1.2. Climatic and soil requirement

Castor requires a warm climate but is severely damaged by frosts. It is grown mostly in *kharif* season, however, in some areas having assured irrigation facilities, *rabi* castor is also grown. In general, sowing with the onset of monsoon is most beneficial under rainy conditions. Since it can be planted in late *kharif* (July-August), therefore any loss to the main *kharif* crop, due to excessive rainfall or very scanty rainfall during onset of monsoon, can be compensated by castor. The crop grows for four to five months and is generally harvested in December and January with assured irrigation, one or two more picking can be taken and crop remain in field up to month of February-March. Castor is usually raised either as a sole crop or mixed crop with *kharif* cereals / millets (sorghum. finger millet, pearl millet, maize); legumes (pigeon pea, groundnut, mung bean, urad dal and cow pea) and sometimes with vegetable crops like chilly, coriander, turmeric and ginger.

1.3. Nutrient requirement by castor and fertilizers recommendation

Castor crop removes 40 kg N, 9 kg P_2O_5 and 16 kg K_2O for production of 1 t seed under rainfed conditions. The removal of 105 kg N for 2.3 t ha^{-1} seed yield was reported under rainfed conditions (Ramanjaneyulu *et al.* 2013). Application of 20 kg S ha^{-1} is recommended if soil has S deficiency. In case of Fe deficiency, application of 15 to 25 kg Iron Sulphate ha^{-1} and for Zn deficient soils, application of 8-12.5 kg zinc Sulphate ha^{-1} is recommended. Further, a crop with 1.37 t ha^{-1} yield potential has removed 86.6 g Zn ha^{-1} on Alfisols

Table 1: Recommended dose of N- P_2O_5- K_2O fertilizers for Castor in different states

State / Region	*Situation or specific conditions*	*N (kg ha^{-1})*	*P_2O_5 (kg ha^{-1})*	*K_2O (kg ha^{-1})*
Tamil Nadu	Rainfed (Varieties)	45	15	15
	Rainfed (Hybrid)	60	30	30
	Irrigated (Varieties)	60	30	30
	Irrigated (Hybrid)	90	45	45
Andhra Pradesh	Rainfed	60	40	30
	Irrigated	80	40	30
Karnataka	Irrigated	75	50	25
	Rainfed	40	40	20
Maharashtra	Rainfed	60	30	0
Madhya Pradesh	Rainfed	40	40	40
Uttar Pradesh	Irrigated	80	30	30
Rajasthan	Irrigated	80	40	0
	Rainfed	40	20	0
Rajasthan (GCH-4 & DCH-177)	Irrigated	120	75	0
Gujarat: Northern region	Irrigated	120	25	0
Gujarat: Saurashtra region	Irrigated	120	50	0
Gujarat: Other regions	Rainfed	100	50	0
Gujarat for GCH-7	Irrigated	180	37.5	0

Source: Oilseeds Division, Department of Agriculture, GOI, New Delhi, 2017

(Suresh *et al.* 2013). Under irrigated conditions, removal of N, P, K and S kg per tonne of castor production was 30.3, 9.8, 15.6 and 3.1, respectively (Patel, 2022); and 6.5 kg CaO and 5 kg MgO (Severino *et al.* 2012).

Castor is a nutrient-demanding crop and responsive to higher nutrient application. In principle, the fertilizer should be applied on the basis of the recommendation of soil testing. Different states of India have either developed or adopted the blanket fertilizer recommendation for commercial castor cultivation on the basis of available soil nutrients status, crop and climatic condition, type of variety or hybrid, season and irrigation facility. Usually, the entire dose of P, K and S and part of N (as specified) is applied as basal and the remaining dose of N is given in splits (around 30 days after sowing and one month interval than after), as and when the soil moisture is adequate (Table 1).

The need for foliar application of fertilizer arise due to (i) adverse soil conditions which favor fixation of applied nutrients especially phosphorus, potassium and micronutrients and converted them to unavailable to plants, (ii) root absorption is slow for some elements and also results in poor translocation within plant, (iii) crop is showing insufficient growth or showing some nutrient deficiencies symptoms (Figure 1), and (iv) relatively larger amounts of fertilizers are required for root supply, and heavy application leads to soil-water pollution. The availability of literatures on the foliar application of plant nutrients on castor is limited. It is therefore imperative to understand the castor plant.

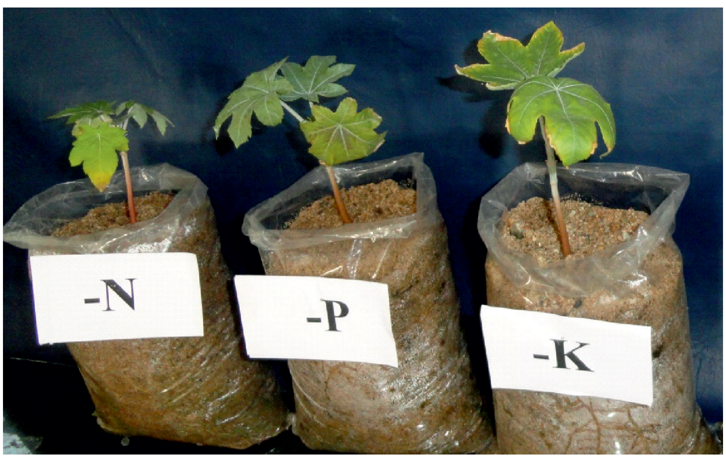

Figure 1: Nitrogen, phosphorus and potassium deficiency symptom in castor

***Castor Plant*:** Castor is a C_3 plant, having great variation in growth and appearance across the locations depending on genotypes. The growth characteristics like plant height, length of primary spike, branching, compactness and flowering are greatly influenced by the environmental conditions that plant height and branching is very much influenced by factors such as soil texture, soil fertility, moisture availability, spacing, etc. Bloom (waxy coating) found on the leaves, stem and certain other part of the castor plant is a natural protection to the plant both from weather adversities and from some insect pests (Kullarni and Ramannamurthy, 1977). Castor contains a toxic alkaloid, Ricinine ($C_8H_8O_2N_2$), apart from other phytochemicals. Ricinine is high in young leaves but disappears in senescing leaves. The entire plant produces Ricin. However, the ricin content in seeds is considerably higher than other portions of plants (Severino *et al.* 2012). Remarkably, castor oil is free from ricin and ricinine. Castor oil is one of the world's most versatile natural products, having a number of medicinal and industrial applications.

Root system: The fertilizer applied to the soil is taken up by the roots. Castor root system is very extensive and comprises main tap root, secondary roots and tertiary roots (Moshkin, 1986). The tap root looks like an extension of the stem below the soil. The roots of castor can go 1.5-4.5 m deep in the soil to quench its water requirement and also have substantial laterals. The secondary roots are branches of the tap root and these are restricted to the upper 30-inch region, secondary roots may spread up to one meter. The tertiary roots are normally 30-45 cm long (Figure 2).

Figure 2: Castor roots showing primary, secondary and tertiary roots.

***Leaves*:** Leaves are large, about 15-45 cm long, with long petioles. The leaves of castor are petiolate, stipulate, dorsiventral, peltate, simple and palmately partite, alternate and 2/5 in phyllotaxy, and glossy with 5-11 lobes. The petiole is fistula, 8-50 cm long, round, pale green or reddish and two glands on either side of the leaf base and one or more glands on the upper surface towards leaf base (Figure 3). The abaxial surface had small isodiametric cells with straight walls. However, the cells of the adaxial side were with thick, shining, undulated anticlinal walls. Epidermal cells on both the surface had distinct protoplasm containing prominent oil globules. There were distinct cuticular striations on the cells (Anand, 1989).

Figure 3: Castor plant showing large leaves with long petiole.

The number of leaves vary among different hybrids and growth stages. The number of leaves increases until harvesting of the first spike and then decreases subsequently. The number of leaves at 30 days after sowing (DAS) were 13, initiation of primary spike was 39 and at the time of harvesting of first order spike were 101 (Patel, 2022).

***Size and distribution of stomata*:** Stomata are found on both the surface of the leaf (amphistomatic). The principal type of stomata is paracytic type. However, anomocytic anisocytic types are also found in the same peel for both the leaf surfaces. Size of the stomata is almost equal on both the surfaces (Table 2). However, the distribution of stomata per unit area on both surfaces of the leaf was variable, being more on lower surface Ref. Fig 4. (Anand, 1989). The stomata appeared to be slightly sunken on the adaxial and abaxial surfaces.

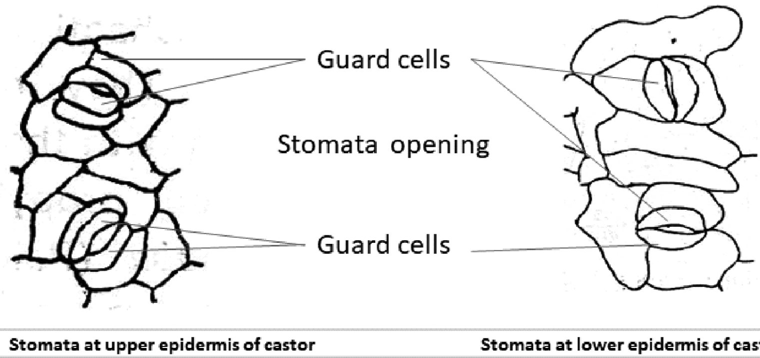

Figure 4: Diagram of stomata of castor on upper and lower epidermis (Adapted from Anand, 1989)

Table 2: Variability in epidermal characters of leaves of castor

Leaf surface	*Stomatal index*	*Stomatal size*	
		Length (µ)	*Breadth (µ)*
Lower	18.1	27.0	15.0
Upper	3.6	26.0	15.5

Ref: (Anand, 1989).

The size of molecules or ions are much smaller to be entered into the castor leaf through stomata (Table 3).

Table 3: The Size of difference ions used for foliar application

Molecule or ion	***Diameter (nm)***	***Molecule or ion***	***Diameter (nm)***	***Molecule or ion***	***Diameter (nm)***
Water	0.275	Ca^{2+}	0.200	Mn^{2+}	0.140
Urea	0.440	Mg^{2+}	0.144	Cu^{+}	0.154
NH_4^+	0.274	Fe^{2+}	0.140	Cu^{2+}	0.146
NO_3^-	0.358	Fe^{3+}	0.120	Ni^{2+}	0.140
PO_4^{3-}	0.476	Zn^{2+}	0.148	Na^{+}	0.204
K^+	0.276	Mo	0.280	Cl^-	0.368
SO_4^{2-}	0.516				

Cuticular wax: The cuticular wax content of castor leaves varied significantly between the cultivars (88.1–139.4 µg cm^{-2}). The main constituent was *n*-Alkanes (ranging from 65.1 to 71.7 per cent of total wax) with nonacosane as main compound. Triacontanoic acid and triacontanol were the major compounds found for *n*-fatty acid and *n*-primary alcohol classes, respectively (De Araujo Silva *et al.* 2017).

2. Foliar Application of Nutrients

Although most nutrients required by castor plants are absorbed through the root system, leaves, flowering plants (and to a lesser degree growing stem) can absorb limited amounts of nutrients. Foliar fertilization means applying nutrients to plant leaves. Foliar application of nutrients is more beneficial than soil application to increase concentration of these nutrients in plants, by increasing the rate of photosynthesis and leading to a better transfer of these nutrients from the leaves to the growing seeds (El-Ramady *et al.*2016). The foliar fertilizers are also performed mostly by the transcuticular pores 'cuticles' on foliage, which are open virtually all the time compared to stomata. Nutrients also enter stomata, but these often are closed due to environmental stresses and darkness. Nutrient solution can stay for longer time on castor leaf, this feature makes castor leaf suitable for foliar application of nutrients.

2.1. Mechanisms of foliar uptake

The nutrients dissolved in water when sprayed have to be first absorbed by the leaf before translocation to other parts. The absorption by the leaf involves surface adsorption, passive penetration through the cuticle, and active absorption by the leaf cells beneath the cuticle (Kannan and Wittwer, 1967). The cuticular membrane of the leaf is the first barrier for nutrient absorption. It is non-cellular and consists of two or more layers, the outer one of cutin and wax, and the inner one of cutin, wax and cellulose. A third layer of pectin and cellulose has been noted in some leaves (Frey-Wyssling, 1976). According to Haas and Schonherr (1979), the lipid content of the cuticle of the leaves do not affect water entry. Numerous pores and canals have been identified in the cuticle, through which the waxes are extruded to the outer surfaces. Foliar nutrient obeyed Fick's law of diffusion. Scanning Electron Microscopy revealed that in castor, cuticles are covered with a thick cuticular layer and are devoid of wax crystals on both surfaces (de Araujo Silva *et al.* 2017). The inner surface of the cuticle adjoins the walls of the epidermal cells, and therefore the ions have to enter the cell wall before absorption by the epidermal cells. However, the cell wall gives way for nutrient movement through apoplastic region. The nutrients after passing the cuticle and the cell wall reach the intercellular space and it is absorbed by the leaf cells. The entry of solutes across the cell membrane, plasmalemma, requires energy derived (active uptake) from the metabolic process of photosynthesis or respiration (Kannan, 1970; Smith and Epstein, 1964). Many of the nutrient elements are actively absorbed by the systems. Light is found to enhance the absorption (Jacoby, 1975).

2.2. Transport of nutrients within and from the leaf

There are two pathways for the movement of solutes within the leaf, before reaching the conducting system for further translocation. The apoplastic pathway is essentially passive. The transport through the symplast is faster than through the apoplast. The foliar absorbed nutrients largely move through the plasmodesmata to other cells, reach the sieve elements of the conducting tissues of the midrib, and petiole and are transported to the shoot and root. It is considered that there are no symplasmatic connections between the guard cells and other cells of the epidermis. Transpiration which is affected by growth substances do not affect nutrient transport, which is indirect evidence that stomatal opening or closing does not affect foliar uptake (Erwee *et al.* 1985). The nutrient supplied to the leaves reach the stem and roots through the conducting systems of the leaves presumably through the phloem and follow the pathway of photoassimilates.

On the basis of movement of nutrients in plants (after absorption) the essential plant elements are grouped into three categories (Table 4).

Table 4: Categorization of essential plant nutrients on the basis of mobility in plant

Sr. No.	*Category*	*Elements*	*Remarks*
1	Freely mobile	N, P, K,	Primary nutrients
2	Partially mobile	Fe, Mn, Zn, Cu, Mo,	Micronutrient
3	Relatively immobile	S, Ca, Mg, B	Secondary nutrients except B

2.3. Foliar uptake of macronutrients

Nitrogen is one of the major elements required in large amounts. Castor leaves can absorb inorganic and organic nitrogen (urea, ammonium, nitrate and others) through stomata and cuticle openings. The cuticles are lined with negatively charged molecules that favor faster uptake of cations (such as ammonium) than anions (such as nitrate). Uptake of small, uncharged molecules, like urea, is also fast. Urea is a common foliar fertilizer because of its uncharged, high solubility and rapid and efficient absorption by leaves. Once urea is absorbed by leaves, it is broken down into ammonia and carbon dioxide by urease enzymes found even in the leaves. Younger and growing leaves have more urease activity than senescing older leaves. Some parts of urea are translocated as urea itself. The N^{15} study indicates very rapid hydrolysis of urea-N and rapid assimilation by leaf tissues. Foliar application of urea is absorbed by the leaf within two days after application. Knoche *et al*. (1994) reported that urea is a highly diffusive molecule with a similar structure to that of water. The relative absorption, translocation, and assimilation of foliar-applied nutrients follow urea > ammoniacal > nitrate. There is positive correlation between the number or density of stomata and the intensity of mineral nutrient uptake from foliar sprays, because the density of cuticular pores is high in cell walls between the guard cells and subsidiary cells. The foliar application is credited with the advantage of fast, efficient and effective use of nutrients, eliminates losses through leaching and stabilization and helps regulate the absorption of nutrients by plants (Manonmani and Srimathi, 2009). Foliar urea absorption is affected by external factors such as temperature and moisture. High leaf surface moisture followed by drying during urea application can cause nitrogen losses from ammonia volatilization (Peuke, *et al*. 1998). The foliar nitrogen assimilated mostly in the shoots and hence phloem transport of inorganic N to the root was negligible. In the case of foliar application of phosphorus nutrient, it was found that phosphoric acid was more effective than mono potassium phosphate (Hussein *et al.* 2015).

2.4. Foliar uptake of micronutrients

The foliar application of Iron and Zinc was found more effective than the soil application in rainfed castor. Foliar spray of 0.5 % Fe and 0.5 % Zn on castor leaf at 50 days after sowing was done. The per kg use efficiency of 0.5 % Fe (foliar application) was nearly 6.9 times more than soil application of 15 kg $FeSO_4$ and 0.5 % Zn as foliar application was 6.7 per cent more than soil application of 15 kg $ZnSO_4$ (Ramanjaneyulu, *et al.* 2021). Foliar application of micronutrients considerably improves the seed yield of castor bean, particularly if these micronutrients were applied together at flowering stage of first raceme + at flowering stage of secondary racemes (Salamatbakhsh *et al.* 2012).

Boron (B) is regarded as practically phloem immobile. The boric acid has high membrane permeability and is considered as more suitable for xylem transportation. In *Ricinus communis* L. cv. Impala, in seedlings B, was highly mobile (without xylem flow). The degree of mobility and the within-plant distribution of B were strongly relative humidity dependent. At RH of 70% or above, up to 16–24% of the B was translocated to other plant parts, at RH (70–80%), the foliar boron accumulates in roots whereas at lower RH no significant movement of B was detected suggesting that in *R. communis* phloem B mobility is not constant, but strongly affected by transpiration rates (Eichert and Goldbach, 2010).

Improvement in oil content and quality: The castor oil content is affected by foliar application of nutrients. The foliar application of chemical fertilizers had a positive effect on the biological as well as seed yield of castor (Table 5). The increase in oil content was due to K that enhances the enzyme activity and S as an integral part of the sulph-hydral (-SH) group, which is essential for the biosynthesis of oil (Osati *et al.* 2022)

Table 5: Effect of foliar application fertilizers at 90 DAS on studied traits of Castor

Foliar application	*Biological yield (t/ha)*	*Seed yield (t/ha)*	*Oil Percent*
S (2000 ppm)	3.36cde	0.90d	48.25bc
K (3000 ppm)	3.32e	0.82e	47.38bc
N (3000 ppm)	4.15bc	1.04b	47.13c
S+K	3.91bcd	0.97bc	48.33c
S+N	3.71cde	0.91c	50.94ab
K+N	4.31ab	1.03b	48.00c
S+K+N	4.78a	1.19a	52.19a
Control	3.36de	0.84e	45.69c

Among the fatty acids of castor, linolenic acid was significantly affected by the foliar application of nutrients. The highest ricinoleic acid (87.35%) and oleic acid (5.54%) concentrations were obtained under full irrigation and foliar application of N and S. (Sadeghi *et al.* 2020). The summary of elements applied on castor as foliar application is given in Table 6.

2.5. *Injuries due to over dose*

At the N level of 1.0 g L -1, no leaf injury was observed with the application of urea, nitrate, or ammonium (in tomato). Tan *et al*. (1999) reported that urea was safer than nitrate N fertilizers (Table 7). The over dose injuries symptoms in case of urea were marginal scorching.

Leaf injury caused by urea was not affected by the solution pH. Increase of the solution pH enhanced the leaf injury caused by ammonium and decreased that caused by nitrate. The injury caused by ammonium was due to the accumulation of NH_4^+ in the applied leaf. The leaf injury caused by nitrate could be due to excess accumulation because nitrate was slowly assimilated by the leaf tissues. Bowman and Paul (1992) reported that foliar-absorbed NO_3^- caused severe leaf damage due to storage in the vacuoles and slow release

Table 6: Elements applied on castor as foliar application

Particular	Chemical/ compound	Dose	Reference
Nitrogen	Urea	2-3 %	Satyagopal *et al.* 2014
Sulphuric acid	Sulphuric acid	0.1%	John Daniel, *et al.* 2018, https://agricoop.nic.in/sites/ default/files/ RAJ29Hanumangarh.pdf
Thiourea	Thiourea	0.05 %	https://agricoop.nic.in/sites/ default/files/ RAJ29Hanumangarh.pdf
NPK	19-19-19, 20-20-20, 21- 21-21	1 %	https://agricoop.nic.in/sites/default/files/ AP17%20Prakasam%2031.1.2011.pdf
NK	KNO_3 (13-0-45)	2 %	https://agricoop.nic.in/sites/default/files/ AP17%20Prakasam%2031.1.2011.pdf
Multi-micronutrients mixture	multi-micronutrients mixture Grade-IV	1%	http://www.jau.in/attachments/ proceedings/1CropProductionF.pdf
Humic acid	Humic acid	25 g/100 L	Rahbari *et al.* 2021
Plant growth regulator consortia	Plant growth regulator consortia	0.05 %	https://tnau.ac.in/tcrs-yethapur/crop-management/
Zinc	Zinc sulphate	0.03 %	Bushra Abbas Taher and Ahmed Hassan Yassin, 2022.

Table 7: Injuries due to over dose of nutrients and their symptoms

Ion or fertilizer	*Injurious starting dose (g/L)*	***Symptom on leaf***
Urea	10	Slight marginal scorch
Nitrate	5	Overall desiccation with tip necrosis
Ammonium	2	Collapse and bleaching of the leaf tips over a distance of 1.5 cm

from the vacuoles. Foliar application of ammonium is beneficial when roots become weak.

2.6. Factors influencing foliar uptake of nutrients

The first barrier to foliar uptake is the cuticle, the surface of which is however not smooth, and is covered with waxy layer, protuberances and structures like trichomes which increase the surface tension. Therefore, any additive included in the aqueous sprays should reduce the surface tension and increase the surface area of absorption. These are obtained by wetting agents and surfactants which are now commercially available for different nutrient elements and crops (Swietlik and Faust, 1984). Young leaves have been found to absorb nutrients more effectively than the old and mature ones. The temperature and relative humidity affect the uptake by providing a thin layer of moisture on the leaf surface through transpiration. The chemical forms in which the nutrients are supplied are also important.

2.7. Characteristics of water soluble fertilizers

Water has the ability to dissolve the fertilizers, ionic and organic substances. Water molecule has the ability to act as an acid or base. This is because of the chemical composition and physical attributes, along with its high dielectric constant, which makes it the most solvent substance. The availability of positive and negative charges with hydrogen and oxygen respectively allows it to attract with other molecules of compounds, disrupting their molecular forces and allowing them to disintegrate and dissolve. Water Soluble Fertilizers dissolve completely in water and a precisely controlled amount of nutrients in a given time period can be delivered. Characteristics of water soluble fertilizers-

- The nutrient element must be present in form of readily available to the plants
- High purity, fully soluble fertilizer, composed entirely of plant nutrients (P & K)
- Use lowest salt index fertilizer
- Spray solution is buffered at pH
- No heavy metals
- Absence of nitrogen allows for balancing / controlling N independently
- Balanced nutrient composition
- Excellent physical properties

2.8. Drawbacks to foliar fertilization

Inability to apply large amounts of nitrogen, phosphorus and potassium without potentially burning the foliage. Therefore, frequent applications of the right fertilizer and fertilizer blends at a low volume are required to maintain optimum tissue levels of key nutrients, resulting in consistent plant growth and functions like the production and transference of assimilates. Crops treated with foliar spray tend to have a higher nutritional value. The contact angle is used to characterize the droplets deposited on the leaf surface. A surface is considered hydrophilic when the contact angle is less than 90°, otherwise, it is considered hydrophobic. Some surfaces can show super-hydrophobicity when the contact angle of a drop on the surface is above 160° (Tang *et al.* 2008).

3. Conclusion

Foliar application of nutrients is the best technique for mitigating nutritional abnormalities and correcting nutrient deficiencies in castor besides has capacity to increase production quality of castor oil. The castor leaves have the ability to absorb plant nutrients. In case of plant nutrients deficiency, the castor leaves can be applied through foliar application of nutrition. The urea, DAP, and water soluble fertilizers (including micronutrients) can be sprayed to the castor leaves. The efficiency of foliar fertilizers is more than the soil application of nutrients. However, suitable spraying tools need to be standardized for getting maximum benefit of foliar fertilization.

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