# MANAGING SALINE AND ALKALI SITUATIONS FOR OPTIMIZING OILSEEDS PRODUCTION

केन्द्रीय रुक्ष क्षेत्र अनुसंधान संस्थान, जोधपुर

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**Central Arid Zone Research Institute**

(Indian Council of Agricultural Research)

Jodhpur - 342 003, INDIA

# MANAGING SALINE AND ALKALI SITUATIONS FOR OPTIMIZING OILSEEDS PRODUCTION

D. Kumar
Sr. Scientist

Central Arid Zone Research Institute,
Jodhpur 342 003, India

**Central Arid Zone Research Institute,**
**Jodhpur**

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## Foreword

It is paradoxical that inspite of occupying world's largest acreage (35%) of oilseeds, India produces less than 7% of edible oil to meet the demand of its one-sixth of the world's population. Ever increasing requirement of fats and oils due to continued spurt in population pressure (@ 2.2% per annum) and sluggish oilseed growth rate (2.04% per annum) is causing imbalance in Indian oilseeds economy. In view to meet the targeted growth rate, it is imperative to considerably enhance production of oilseeds in various ecological zones under various biotic and abiotic constraints.

Salinity is a severe constraint in realization of fullest potential of crops including oilseeds. Oilseed crops exhibit wide array of response towards problem soils and poor quality waters. Production of annual oilseeds in general; and sesame, groundnut, rapeseed-mustard and linseed, particularly, is considerably reduced due to poor seedling emergence resulting in patchy and uneven plant stand. In view of gravity of such problems, it is desired to direct our efforts in compiling such research results which could be helpful in enhancing oilseeds production on problem soils and with poor quality irrigation waters so that import bill on edible oils is cut down in India.

The information compiled and being presented in the form of a technical bulletin entitled "Managing Saline and Alkali Situations for Optimizing Oilseeds Production", is timely and called for. I am sure, the same would be helpful to enhance, sustain and stabilize the oilseeds production on saline situations in arid and semi-arid areas of the country.

I congratulate the author who has long association with salinity research on oilseeds, for bringing out this bulletin.

Place : Jodhpur
Date : 1st January, 1998

**A.S. Faroda**
**Director**

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Place : Jodhpur

Date : 1st January, 1998

**D. Kumar**

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## INTRODUCTION

Irrespective of the source of irrigation waters, some amount of salts are always dissolved therein. Similarly, all types of soils also, contain a mixture of soluble salts, some of which are essential for its productivity. However, simply defined, salinity is the excessive concentration of soluble salts in irrigation water and/or in the soil, and is practically referred to as the inherent problem of irrigated agriculture. This menace is of more concern in semi-arid and arid tracts, characteristically having excess of evapotranspiration than precipitation, therefore, salts continue to move upward and accumulate in the upper surface of the soil causing salinity problem (Epstein *et al.*, 1980).

Expression of salinity varies much and depends on its purpose and the measurement. In general plant and soil scientists express electrical conductivity (EC) of the soil or water as in mmhos $cm^{-1}$ or $dS.m^{-1}$ (milli mhos $cm^{-1}$ or deci simen/meter, respectively) while water quality engineers express it on weight/volume basis as mg $L^{-1}$, and the soil and bio-chemists prefer to express the same as ppm and mM, the same cause confusion in readers' mind. However, their common and convenient way of expression and some relationship between the units of expression will be quite desired. An average soil or water extract containing 640 mg $L^{-1}$ total dissolved salts is known to have an electrical conductivity of about 1 mmho $cm^{-1}$ or $dS.m^{-1}$ at 25°C or molar concentration of approximately 11 millimol (mM) sodium chloride.

In general saline soils are characterized by having EC of the saturation extract > 4 $dS.m^{-1}$. Salt affected soils also include sodic or alkaline soils. Such soils accumulate excessive quantity of exchangeable Na on their cation exchange sites. High values of exchangeable sodium in alkali soils may have presence of sodium carbonate salts in varying amounts. Exchangeable sodium percentage (ESP) of the alkali soils may vary from 15 to as high as 100 and pH of the extract is always higher than 8.5 and EC generally lower than 4 mmho $cm^{-1}$ (Abrol *et al.*, 1980). Alkali soils may be saline or non-saline. Saline and alkaline soils may be natural or they may represent secondary salinization due to poor quality irrigation waters.

## EXTENT

Salinization and alkalinization of the soil are serious impediments in obtaining higher crop yields in sizeable lands of the country. According to an estimate more than 7 million hectares of otherwise productive lands of the country have virtually gone out of cultivation. Extent of the problem can be described in following 3 major groups:

### Semi-arid and Indo-gangetic Alluvial Sub-plains

Country's most fertile belt in Punjab, Haryana, Uttar Pradesh, Delhi and Bihar with an area of about 2.4 million hectares are affected with sodicity problem. In Punjab, nearly 0.6 million hectares salt affected soils are in Amritsar, Gurdaspur, Sangrur, Kapoorthala, Feerozpur, Faridkot and other pockets. Na is the most important cation occurs to the extent of 90%. Carbonates and sulphates predominate in salt affected soils of good internal and poorly drained soils, respectively.

In Haryana, total salt affected areas are estimated to be 525 lakh hectares. Two main classes viz., saline and alkali soils occur in distinct zones, the former tends to occur in regions receiving annual rainfall less than 550 mm, while alkali soils occur in regions having mean rainfall 550-900 mm. Alkali soils occur in Jind and parts of Mahendragarh, while saline soils occur in Sonipat, Hisar, Rohtak, Jind, Bhiwani, Gurgaon and Sirsa. Furthermore, extensive areas in Gurgaon, Mahendragarh and in arid tracts of Bhiwani, Hisar and Sirsa districts possess neutral soluble salts at some depth having deep profile poor quality groundwater.

In Uttar Pradesh, 1.25 million hectares areas are salt affected. Areas falling in Districts of Aligarh, Azamgarh, Bareilly, Etah, Etawah, Ghaziabad, Hardoi, Sultanpur, Pratapgarh, Unnao, Kanpur, Meerut and Rai-bareilly are mainly affected by sodicity problem.

Besides, the underground waters of the areas adjoining Rajasthan are more saline than those of hilly, central and eastern zones.

### Coastal and Deltaic Areas

Salt affected soils in India are spreaded in sizable areas of 2.5 million hectares in coastal tracts like, West Bengal (0.80 m ha), Gujarat (0.714 m ha), Orissa (0.400 m ha), Karnataka & Goa (0.086 m ha), Andhra Pradesh and Maharashtra (0.04 m ha, each), Kerala (0.06 m ha) and Tamil Nadu (0.004 m ha). Frequent inudation of sea water has rendered the coastal soils highly saline. These soils are moderate to heavy in texture. Sodic soils are found in few pockets of Andhra Pradesh and Tamil Nadu also.

### Irrigated Arid Regions

Arid zone in India which occupies almost 12.0% of the country's geographic area is, spreaded to 3.2 lakh square kilometers. The arid zone area is mostly occupied by the hot desert of Rajasthan (61%), Gujarat (20%), Punjab(9%) and Andhra Pradesh and Karnataka (10%). The 11.6% of this 12% arid area is salt affected and is mainly distributed in flat plains of Ghagar (0.14 m ha) and great Ranns of Kuchh (2.3 m ha). Saline profiles of these soils are deep. Salt affected soils in Rajasthan are approximately 1.97 million hectares in Districts of Ajmer, Alwar, Kota, Chittorgarh, Tonk, Jodhpur, Jaipur, Nagore, Pali, Bharatpur, Bhilwara, Banswara and Sawaimadhopur.

## SEVERITY

Salinity menace due to its continued horizontal and vertical expansion is being realized as a serious obstacle in economic utilization of land and water resources in India. According to the available estimates, almost 15% of the total cultivated lands in India are influenced by salinity. The problem is of serious concern in arid regions particularly, in Rajasthan, where more than 56% of the cultivated lands are under salinity threat. In 12 districts of Western Rajasthan, the problem is further accentuated because of the fact, 84% of the underground waters being used for irrigation are saline (ECw 2.5-40.0 $dS.m^{-1}$). Ruthless use of brackish water, lack of secondary source of irrigation, impaired sub-surface drainage, encountered with harsh arid climate, have contributed to the development of saline waste lands to the extent of 1.97 million hectares which have gone completely out of cultivation.

Situation is almost the same in great Rann of Kachh in Gujarat and problem is also alarming in arid regions of Punjab, Haryana and parts of Uttar Pradesh. These areas exhibit considerable salt build-up in the rhizospheres during *rabi* and the same is not substantially leached down due to scarce rainfall and high evapotranspiration. Farmers hesitate in growing oilseeds in such conditions, however, even if, the sowing is done their production is disheartening. Thus, area and production both are steadily going down in respect of sesame, groundnut and castor on salt affected soils of arid region.The situation continues to remain alarming even in *rabi* season because of more salt build-up takes place due to capillary rise of salts in the sub soil. Seedling emergence of rapeseeds and mustard are, therefore, very drastically reduced at ECw 8 $dS.m^{-1}$ onwards leading to drastic reduction in yield production. Salinity is, therefore, considered a very serious threat for oilseeds production in irrigated belts of arid zone.

Country's most fertile belt of Indo-gangetic plains of Punjab, Haryana, Uttar Pradesh and Bihar is influenced with the severity of soil sodicity. Thus, due to impaired infiltration, aeration, penetration and absorption resulting from deteriorated physical property of the soil, seedling emergence of small seeded oilseeds (rapeseeds, mustard, sesame, linseed etc.), in particular, fails to occur (at pH9.0-9.4) resulting in poor harvest. The soils are highly sodic. Furthermore, high rainfall (Ca 900 mm annually) and higher water table associated with poor sub-suface drainage make these soils difficult to manage for better oilseeds production. Certain pockets in Punjab, Haryana and Uttar Pradesh, and adjoining Rajasthan characteristically show poor quality underground water (ECw 2.5 to 25.5 $dS.m^{-1}$) which is not at all ideal for successful cultivation of oilseeds.

Thus, due to high soil salinity and lack of good quality water, the areas in these parts remain mono-cropped in rainy season. Hence, rapeseed-mustard in West Bengal; sunflower and safflower in Andhra Pradesh, Karnataka and Maharashtra and castor in Maharashtra and Andhra Pradesh are being cultivated in sizable pockets with saline water application. Safflower and castor being highly susceptible towards the seedling emergence stage, suffer heavy yield losses, quantitatively yield level to the extent of more than 50% are reduced at the salinity levels of ECe 6-8 $dS.m^{-1}$ in respect of castor and 8-10 $dS.m^{-1}$ for safflower, particularly, in heavy soils.

Hence, careful monitoring and management of saline situations prior to, at the time of planting and during cropping period of the concerned crop, is quite logic for enhanced and sustained production. Attempts have been made to bring out some of agro-techniques developed in semi-arid and arid regions, which would help supplement management in respect of oilseeds production in different regions of India.

## CROP PRODUCTION

### Reclamation

Sodic soils are inherently poor in physio-chemical properties, hence special remedial measures are needed for their effective utilization in crop production programme. Before planting of crops, in highly sodic soils, following remedial steps are suggested for their reclamation, with a particular reference to Indo-gangetic plains.

*Levelling and bunding*

Levelling of soil is initially and logically the first step in reclamation process. It will ensure uniform placement of amendment resulting in enhancement of reclamation process. Bunding all along the boundary (30-40 cm) will be helpful in harvesting rainwater to the desired extent (Tyagi, 1982).

*Availability of irrigation water*

Good quality water is an important input and must be ensured by installation of tubewell or by secondary source. However, in case of poor quality underground water being the only source, like in arid areas, reclamation process shall have to be repeated after every 2nd or 3rd year depending on the situation and the quality of water.

*Drainage*

Provision must be made for draining out of extra water by sub-surface drainage system.

*Application of amendments*

Gypsum, sulphur and pyrites are most commonly used amendments for reclamation of such sick soils. *Dhaincha* (*Sesbania aculata* L.) has been found the best green manuring crop for alkali soils. It has potential to withstand alkalinity (9.5 pH), waterlogging (1.5-1.8 mm) and good rotability. It also contains higher Ca and highly acidic juice (Dhawan *et al.*, 1958). Incorporation of green manuring brings about improvement in physical properties of alkali soils and thus, facilitates dissolution of Ca from native $CaCO_3$ and the replacement of Na from exchange site (Somani *et al.*, 1990).

Gypsum has been observed the most effective chemical amendment. During its application, Na is replaced by Ca and the former is replaced from the exchange site and leached below the root zone. Efficiency of gypsum is more with the fineness hence,

**Table 1. Effect of different levels of gypsum on the seed yield (kg $ha^{-1}$) of oil crops**

| Gypsum ($t\ ha^{-1}$) | Toria (Sangam) 1981 | Toria (Sangam) 1982 | Brown sarson (BSH-1) 1981 | Brown sarson (BSH-1) 1982 | Indian mustard (Prakash) 1981 | Indian mustard (Prakash) 1982 | Taramira (T-27) 1981 | Taramira (T-27) 1982 | Mean (kg $ha^{-1}$) 1981 | Mean (kg $ha^{-1}$) 1982 |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.25 | 490 | 510 | 370 | 820 | 1020 | 1020 | 360 | 470 | 460 | 705 |
| 12.50 | 730 | 860 | 440 | 910 | 1140 | 1140 | 430 | 580 | 590 | 872 |
| 18.75 | 760 | 860 | 470 | 910 | 1240 | 1240 | 430 | 590 | 610 | 900 |
| 25.00 | 690 | 780 | 440 | 910 | 1170 | 1170 | 420 | 510 | 640 | 935 |

CD 5% for gypsum 1981, 59; 1982, 70.
CD 5% for crop 1981, 67; 1982, 80.
Source: Annual Progress Report, CSSRI, 1982.

it may be graded and ground to pass through 100 mm sieve (Richards, 1954). The quantity of the gypsum to be added depends on the soil analysis. In worst affected soils (pH 9.5) gypsum @ 15 t $ha^{-1}$ or more may be required depending upon the soil texture and the level of ESP to be brought down. The quantity of gypsum may also depend on the intended crops to be cultivated following reclamation process. It is advised that gypsum may be mixed in 8-10 cm soil depth for shallow rooted oilseeds (groundnut, sesame) but 20-30 cm reclamation of soil is advised for deep rooted crops (Castor, mustard, sunflower etc.) More quantity of gypsum is therefore, needed for deep rooted crops.

Rapeseed-mustard (particularly, toria, brown *sarson*, Indian mustard and taramira) being very susceptible towards sodicity, fail to germinate at all, at pH 10 on clay loam soils of Karnal without gypsum applications. However, yield of these crops can be increased with increasing gypsum quantity upto 12.5 t $ha^{-1}$ at a inter row spacing of 40 cm. Results reported from Karnal, indicated that gypsum application @ 12.5, 18.7 and 25.0 t $ha^{-1}$ were at par but significantly superior to 6.2 t $ha^{-1}$ of gypsum application. Thus, Brassicas could be successfully raised, even at 10 pH following 12.5 t $ha^{-1}$ of gypsum applied before sowing as amendment. (Table 1).

Use of gypsum as an amendment in reclamation of sodic soils has proved more effective when applied in combination with FYM (Bhumbla, 1972). In a recent study conducted on highly sodic soils of Kota in dryland situations, the application of gypsum @ full GR + FYM @ 10 t ha$^{-1}$ proved very useful in lowering down the pH (9.38 to 8.15) and ESP (61.67 to 41.08). Seed yield of taramira (cv. Durgapura complex) consequently increased from 2.5 at control (pH 9.38, ESP 61.67) to 7.6 q ha$^{-1}$ in the treatment with full gypsum + FYM @ 10 t ha$^{-1}$. Thus, yield increment by several folds justifies that taramira can be safely cultivated on reclaimed soils having pH 8.15 and ESP 41 (Table 2).

*Cropping of reclaimed soils*

Cropping of reclaimed soils with sodic tolerant crops is advised so as to enhance reclamation process which otherwise takes several years. Following cropping sequences for oilseeds are suggested.

*Sandy loam light textured soils (Arid zone)*

Ist Year : Fallow/clusterbean-safflower.

**Table 2. Effect of amendments on the properties of sodic soils and seed yield of taramira (cv. Durgapura comples)**

| Treatment | pH | ESP | Seed yield (q ha$^{-1}$) | Stover yield (q ha$^{-1}$) |
|---|---|---|---|---|
| Control | 9.38 | 61.67 | 2.5 | 8.1 |
| FYM @ 10 t ha$^{-1}$ | 9.25 | 59.54 | 4.3 | 12.3 |
| Gypsum 1/2 GR | 8.80 | 52.72 | 4.8 | 14.9 |
| Gypsum @ full GR | 8.36 | 41.77 | 4.7 | 15.3 |
| Gypsum @ 1/2 GR + FYM @ 10 t ha$^{-1}$ | 8.82 | 50.90 | 5.5 | 16.3 |
| Gypsum @ Full GR + FYM @ 10 t ha$^{-1}$ | 8.15 | 41.08 | 7.6 | 23.1 |
| CD 5% | 0.12 | 02.28 | 0.32 | 01.91 |

Source: Lodha *et al.*, 1997; GR, Gypsum requirement.

*Leaching*

Salts dissolved and developed following reclamation may be leached down by standing water for about 8-10 days in the field. More days of standing of water (rain or irrigation) are better for effective leaching.

IInd Year: Sunflower-taramira.

IIIrd Year: Sunflower/fallow-Indian mustard/linseed.

*Clay loam soils (Indo-gangetic plains)*

Ist year : *Dhaincha*-safflower/linseed.

IInd year: Maize/rice-safflower/sunflower.
IIIrd year: Fallow-Indian mustard.

### Mulching

Surface mulching of saline and sodic soils is very useful, because of the following:

- It improves physical and microbial properties of the soil.
- It enhances reclamation process and prevents crust formation on soil surface.
- By disrupting capillary continuity, it reduces water loss through evaporation.
- It prevents salt accumulation on the upper surface and reduces water requirement (Jain, 1984).

On partially reclaimed soils, application of 10 t $ha^{-1}$ of rice and polythene mulch with 80% soil cover, 1 and 2 irrigations can be saved in case of brown *sarson*, under the treatment of 100 and 75% depletion, respectively. On sodic soils in Indo-gangetic plains, 20-30 t $ha^{-1}$ of rice husk is recommended for improving infiltration rate. Similarly on red sandy loam soils of Bapatla, paddy husk and groundnut shells @ 5 t $ha^{-1}$ each, is recommended to take good harvest of sunflower and safflower with saline water of EC 6-8 $dS.m^{-1}$. Mulching is also suggested on saline soils of coastal areas in West Bengal during preceding uncropped season when adequate moisture is available in the profile (Bandopadhaya and Bandopadhaya, 1982).

### Crop Substitution

In many traditional salt affected areas of Rajasthan, Gujarat, Punjab, Haryana, Uttar Pradesh; areas of medium black soils (Maharastra, Andhra Pradesh, Karnataka etc.); the coastal areas and sodic soils of Indo-gangetic plains; the traditional cereal and pulse crops are less productive. However, there are some salt tolerant oilseed crops if these are substituted, can maximize monetary returns per unit of time and input. Some possibilities regarding substitution of certain unproductive crops in different regions are given in Table 3.

### Intercropping

Intercropping an established safe-guard against natural calamities and vagaries can help extend the area of oilseed crops and provide stability and enhance aggregate yield returns per unit of time and inputs on saline conditions. Certain intercropping patterns (Table 4) can be suggested for different regions under saline conditions (Kumar, 1994).

### Crop Rotation

A best crop rotation is one, which not only provides good return but also helps prevent or reduce the salt build-up in the soil. As far as possible problem soils may not be left fallow. Following crop rotations for specific saline/alkaline zones are advised:

**Table 3. Crops subsitution in favour of oilseeds in different zones and situations of the country**

| Region/situaion | Less productive crops | Substitute crops |
|---|---|---|
| Arid parts of Rajasthan Arid parts of Gujarat | Irrigated wheat and barley, rainfed pearl millet | Mustard and taramira, safflower |
| Parts of Punjab, Haryana, Uttar Pradesh and adjoining Rajasthan | Rainfed wheat, barley and gram | Safflower/mustard/ taramira |
| South East Rajasthan | Linseed, barley and gram | Mustard/sunflower |
| Bundelkhand region | Wheat, niger, gram | Safflower/mustard |
| Parts of Maharashtra and Andhra Pradesh | Rainfed wheat and gram | Safflower |
| Karnataka (Bellary, Dharwad, Bijapur and Belgaon Districts) | Gram, rainfed wheat, corinander and Herbarium cotton | Safflower/sunflower |
| Late receipt of mosoonic rains in arid environment | Cotton, groundnut, pearl millet, clusterbean | Sunflower |

- Sandy loam saline areas (Parts of Western Uttar Pradesh, Haryana and Punjab):
  - » Maize - mustard- green gram/tomato
    Pearl millet- mustard - sunflower.
    (Uttar Pradesh)
  - » Clusterbean - mustard/taramira
    Pearl millet-mustard/barley
    *Dhaincha* (G.M.) - wheat/taramira.
    (Haryana)
    (Anonymous, 1986)
  - » Maize/pearl millet - mustard
    Sorghum - mustard
    Sunflower/maize- toria+ *Brassica carinata* (Punjab) (Qureshi and Karan, 1992)
- Loamy sand light textured soils (parts of Rajasthan and Gujarat):
  - » Clusterbean - mustard/taramira
    Maize- mustard/taramira/safflower
    (Qureshi and Karan, 1992)
    *Dhaincha* (GM) - pearl millet/ sorghum- mustard (Rajasthan)
    (Anonymous 1988)
  - » Pearl millet/castor - mustard/ taramira
    Dhaincha (GM) - groundnut-mustard

**Table 4. Various intercropping systems involving oilseeds at different salinity/sodicity levels in varied agro-climatic situations of India**

| Region | Situation | Intercropping | Ratio |
|---|---|---|---|
| Parts of Western Uttar Pradesh | Saline water upto 6.00 $dS.m^{-1}$ | Potato + mustard | 3:1 |
| | Saline water 6-10 $dS.m^{-1}$ | Wheat + mustard<br>Wheat + taramira | 8:1<br>8:1 |
| | Saline water of 10-15 $dS.m^{-1}$ | Autumn sugarcane + taramira/barley | 1:1 |
| Parts of Central and Eastern Uttar Pradesh | Sodic water of RSC 10 or soil pH 9-9.2 | Linseed + safflower<br>Gram + safflower | 3:1<br>2:1 |
| Western parts of Haryana and parts of Punjab and adjoining Rajasthan | Salinity of water ECw 6 $dS.m^{-1}$ or pH 9.0/10 RSC water | Gram + mustard | 3:1 |
| | Salinity of the water/ soil ranging EC 6-12 $dS.m^{-1}$, soil pH 9.2 | Wheat + mustard | 8:1 |
| | Salinity 12-15 $dS.m^{-1}$ and pH of the soil extract 9.2-9.3 | Barley + taramira<br>Wheat + taramira | 8:1<br>8:1 |
| Parts of Madhya Pradesh, Bihar and Central Uttar Pradesh having medium clay soils | Salinity of the water or soil ranging 4 to 6 $dS.m^{-1}$ or RSC of the water upto 10 meq $L^{-1}$ | Gram + mustard | 2:1 |
| | Salinity of the water/ soil ranging 6-12 $dS.m^{-1}$ | Linseed + wheat | 2:4 or 1:3 |
| | RSC of the water upto 12 meq $L^{-1}$, or soil pH 9.3-9.4 | Linseed + safflower | 2:2 |

(Contd.)

(Contd... Table 4)

| Region | Situation | Intercropping | Ratio |
|---|---|---|---|
| Parts of Mahashtra and Karnataka having medium black clay soil | Irrigation waters having salinity upto 4 $dS.m^{-1}$ | Irrigated wheat + safflower<br>Ragi + sunflower | 3:1<br>6:2 |
| Parts of Andhra Pradesh with red sandy loam soils | Irrigation waters having salinity upto 6-10 $dS.m^{-1}$ | Black gram + sunflower | 4:2 |
| Coastal saline belts of West Bengal | Salinity of the soil/water upto 10 $dS.m^{-1}$ | Wheat + linseed<br>Wheat + mustard | 3:1<br>8:1 |

Source: Kumar, 1994.

*Dhaincha* (GM) - castor-mustard/taramira (Gujarat)

Indo-gangetic alluvial plains representing sodic soils (Punjab, Haryana, Uttar Pradesh and Bihar):

» Rice - taramira/sunflower
*Dhaincha* (GM) - rice-safflower/sunflower (Punjab)

» Cotton- mustard/taramira
*Dhaincha* (GM) + mustard (Haryana)
(Anonymous, 1989)

» Rice - wheat + linseed
Sorghum - mustard/linseed/safflower
Cotton - sugarcane + mustard
(Uttar Pradesh and Bihar)

Coastal saline areas of West Bengal:
Mulch/*Dhaincha* (GM) - rice - mustard
Mulch - Upland rice - mustard - jute

- Red sandy loam soils of Andhra Pradesh:
Hybrid sorghum - safflower
*Dhaincha* (GM) - maize - safflower/sunflower
*Dhaincha* (GM) - castor - safflower

- Medium black clay soils of Karnataka:
*Dhaincha* (GM) - green gram - safflower
sunflower - safflower
Cotton - sunflower/safflower

## Land Preparation

Utmost care is needed in preparation of the problem soil. Effective ploughing of the soil will ensure adequate moisture and will break the continuity of capillaries, therefore reducing salt build-up on the upper surface. Sodic soils which are physically deteriorated, must be deeply and thoroughly ploughed to break the soil hardness and prevent clod formation. Land must be properly bunded and made quite uniform by dividing to roll quarters. Bunding of the land will help prevention of excessive inward flow of poor quality irrigation water and the runoff of the water received through rains will also be checked.

## Sowing Methods

A method of sowing of crops on saline/alkaline soils situation is preferred that ensures lesser salt content in the rhizosphere of seeds. It has been observed that if the sowing of seeds is attempted in ridges within capillary fringes just above the irrigation level in the furrows, will be quite effective. This is because of the fact that salt content will be maximum at the top of the ridge and minimum on its side. Flat sowing must be avoided on salt affected lands. Care must be taken for planting of the crops before the soil dries up.

## Seed Rate and Seed Treatment

Seedling emergence is the most drastically affected trait of almost all the oilseed crops under saline/alkaline situations. (Rai, 1980; Minhas *et al.*, 1990; He and Crammer, 1993a). Therefore, attempts must be made to compensate decreased plant stand through manipulation of seed rates and seed treatments (Kumar and Singh, 1980). Higher seed rate (Ca 25-40%) may be used in case of moderately tolerant small seeded oilseeds-Indian mustard, taramira and linseed under the soil salinity of ECe 8-16 $dS.m^{-1}$. Higher seed rates to the tune of 50-100% however, may be used for bold seeded oilseeds - castor, sunflower, safflower at the aforesaid salinity levels. In case of sesame and groundnut, which are most susceptible for germination under saline situations, seed rate may be doubled at salinity levels of even 4-6 $dS.m^{-1}$ in medium black clay soils and 6-8 $dS.m^{-1}$ in light textured soils.

On sodic soils however, increased seed-rate alone may not be of much use, hence, their pretreatment with RSC water being used for irrigation or with $CaCl_2$ is recommended. In general, soaking of higher seed quantity (50-100% more) of castor, sunflower and groundnut with 3-3.5% $CaCl_2$; and the higher seed rates (25-40%) of other small seeded oilseeds may be treated with 2.5-3.0% $CaCl_2$ for enhancing germinability of seeds and therefore, optimising plant density.

## Improved Varieties

Use of the varieties that withstand well under abrupt saline and sodic conditions is an economic and sustained approach. Use of these varieties vis-a-vis local ones would be quite helpful in enhancing production of oilseed crops. Suitable varieties of the concerned crops, keeping in view the region, level of salinity/sodicity and the soil type can be chosen for planting (Table 5).

## Fertility Management

Fertilizer is an essential energy input for saline and alkaline situations. Fertilizer

| Table 5. Salt tolerant cultivars (cv.) of oilseeds for different situations | | | | | |
|---|---|---|---|---|---|
| Crop | Soil type | Salt tolerance limit of the crop | Tolerant cv. | Tolerance limit of cv. | Reference |
| Indian mustards | Sandy loam light texured soil | ECw 8 | Varuna<br>PR 1002 | ECw 8-9<br>ESP 28 | Rai, 1977 |
| | Sandy loam shallow soils | ECw 6-8 | Varuna | ECw 10 | Anonymous, 1986 |
| | Loamy sand light textured soils | ECw 8-10 | RLC 1357<br>NDR 8604<br>CS 52 | ECe 10-12 | Kumar, 1995 |
| | Clay loam natural saline soil | ECw 8 | RH 30<br>DIRA 337 | ESP 30<br>ECe 10 | Kumar *et al.*, 1983 |
| | Medium clay soil | ECw 6-8 | Varuna | ECw 10 | |
| | Partially reclaimed clay loam sodic soils | pH 9.2 | RID 102 | pH 9.2-9.3 | Anonymous, 1982 |
| | Saline vertisols | ECe 10 | CS 15 | – | Uma *et al.*, 1992 |
| Taramira | Sandy loam light textured soil | ECw 10<br>pH 9 | T 27 | pH 9.2 | Kumar, 1988 |
| | Loamy sand light textured soils (Saline/ sodic) | ECe 10<br>pH 9 | TMH 851 | ECe 12<br>pH 9.2 | Kumar, 1995 |
| Chitti *sarson* (*B. tournifortii*) | Loamy sand duny soils of Bikaner | ECw 10 | RBT 1<br>RBT 2 | ECw 10<br>ECw 10 | Anonymous, 1996 |
| Linseed | Loamy sand light textured soils | ECe 10<br>pH 9.2 | KL 169<br>KL 169 | ECe 12<br>pH 9.2 | Anonymous, 1987 |
| | Medium black clay soil | ECe 6-8 | LMH 81-23<br>LMCK 166<br>C 219-7-1 | ECe 10 | Anonymous, 1986 |

(Contd.)

(Contd... Table 5)

| Crop | Soil type | Salt tolerance limit of the crop | Tolerant cv. | Tolerance limit of cv. | Reference |
|---|---|---|---|---|---|
| Linseed | Coastal saline soils | ECe 10 | NP 71<br>C 219-2 | ECe 13.3<br>ECe 11.8 | Rai & Sinha, 1980 |
| Safflower | Sandy loam light soils | ECw 10<br>pH 9.2 | N 7<br>IC 11842 | ECw 12<br>pH 9.3 | Rai, 1977 |
| | Loamy sand light textured soils | ECe 12<br>pH 9.2 | HUS 507<br>HUS 3047 | ECw 12-14 | Anonymous, 1987 |
| | Coastal saline soils | ECe 12 | HUS 305 | ECe 12-14 | Anonymous, 1985<br>Janardhan *et al.*, 1986 |
| | Medium black clay soils | ECw 6 | A 1<br>19-185 | ECw 8<br>ECw 8 | Patil *et al.*, 1989 |
| | Medium black clay soils of Dharwad | ECw 6 | B3-1657 | ECw 8 | Rao *et al.*, 1987 |
| Sunflower | Loamy sand light textured soils | ECe 10 | NSH 30 | ECe 12 | Kumar and Tarafdar, 1989 |
| | Medium black red sandy loam soils | ECw 6 | EC 68413 | ECw 8 | Anonymous, 1986 |
| | Soils of Coimbatore | – | EC 68413 | 0.52% salt | Bhatt and Indirakutty, 1973 |
| | Medium black clay soils of Bangalore | – | EC 68415<br>SEH 4 | ECe 7.5 | Chandru *et al.*, 1987 |
| | Clay soils of Dharwad | – | Ransom<br>Record<br>US 10 | ECw 8<br>ECw 12<br>ECw 12 | Anonymous, 1986<br>Anonymous, 1986<br>Anonymous, 1987 |
| Groundnut | Sandy loam light texured soils | ECw 6<br>pH 8.8 | JL 24 | pH 9 | Kumar, 1984 |
| | Red sandy loam soils | ECw 4 | TMV 10 | ECw 4 | Karadge and Chavan, 1981 |
| | Sandy soils of Bikaner | ECw 4 | SB XI | ECw 7.5 | Anonymous, 1996 |
| Castor | Loamy sand light soils of Jodhpur | ECw 10 | SA 2 | ECe 10-12 | Kumar & Daulay, 1988 |
| | | | VI 9 | ECe 10 | Kumar *et al.*, 1989 |

efficiency, however depends on many biotic and abiotic factors. Hence, a perfect dose and the kind of fertilizer must be carefully decided. A judicious dose of fertilizer, its form and source be chosen to satisfy following three main objective:

- To provide readily available essential nutrients,
- to help mitigate adverse effects of poor quality irrigation water and deteriorated soil properties and,
- to promote growth and yield of plants.

Organic fertilizer has been observed better than inorganic fertilizer on both saline and alkaline conditions, therefore it must be regularly applied. *Dhaincha* (*Sesbania aculata* L.) is rated most important source of green manure and efficient source of the reclamation of sodic soils. It withstands waterlogging and saline-alkali conditions (Yadav and Agarwal, 1961 and Kanwar, 1962). It also helps reduce the requirement of N on sodic soils. Application of 20 kg N $ha^{-1}$ with *Dhaincha* for green manuring has proved equally good to 80 kg N $ha^{-1}$ for Indian mustard (Somani *et al.*, 1990). On red sandy loam soils of Andhra Pradesh (Bapatla) and on medium black clay soils of Karnataka (Dharwad), the application of FYM and gypsum @ 5 t $ha^{-1}$ each has been observed useful for mitigating harmful effects of RSC 10 meq $L^{-1}$ and EC 10 $dS.m^{-1}$ of irrigation water. On these soils therefore, gypsum and green manuring are advisable.

Due to decreased availability and leaching of chemical fertilizers, in general 50% higher doses of N and P are recommended on both saline and sodic soils (Chouhan *et al.*, 1988 and Kumar, 1995). In sodic conditions, the application of $ZnSO_4$ and gypsum are very essential (Chhabra, 1982).

Research data available from 4 years of consecutive response study of nitrogen and phosphorus application in Indian mustard (cv. Varuna) with saline water application upto ECw 16 $dS.m^{-1}$ appears quite worthwhile. Seed yield decreased by 38% at the salinity level of 16 $d.Sm^{-1}$ over control. This resulted in sharp response in seed yield of mustard at 60 and 90 kg N over 30 kg N $ha^{-1}$ (Table 6). On sandy loam soils of Karnal, notwithstanding the lower magnitude of adverse effects of ESP (24-30), the yield increased upto 120 kg N $ha^{-1}$ in Indian mustard (cv. Pusa Bold). Such response appears to be possibly due to nutritional deficiency which is common in alkali soils.

Six-year consecutive study (1990-91 to 1995-96) conducted on sandy loam soils of Agra to study the impact of poor quality irrigation waters (ECw 12 $dS.m^{-1}$ and SARw 10 meq $L^{-1}$) on rotational system of sorghum for fodder in *kharif* and Indian mustard (Pusa Bold) in *rabi* has yielded encouraging results (Table 7). Results revealed that additional dose of nitrogen (125%) over recommended one (60 kg N $ha^{-1}$) did not produce significantly higher fodder yield of sorghum, however, it did produce markedly higher seed yield in In-

| Table 6. Seed yield (q $ha^{-1}$) of Indian mustard as affected by salinity levels | | | | | |
|---|---|---|---|---|---|
| Treatment | 1984-85 | 1985-86 | 1986-87 | 1987-88 | Mean |
| **ECw ($dS.m^{-1}$)** | | | | | |
| 3 | 8.3 | 10.4 | 19.0 | 18.4 | 14.25 |
| 8 | 8.9 | 9.3 | 15.9 | 16.2 | 12.57 |
| 16 | 6.2 | 5.5 | 12.4 | 0.6 | 6.17 |
| CD 5% | 1.1 | 1.9 | 3.0 | 3.9 | |
| **N levels (kg $ha^{-1}$)** | | | | | |
| 30 | 5.6 | 6.5 | 13.5 | – | 8.53 |
| 60 | 7.4 | 8.0 | 12.3 | 10.1 | 9.45 |
| 90 | 10.7 | 10.7 | 16.6 | 12.4 | 12.60 |
| 120 | – | – | – | 12.6 | 12.60 |
| CD 5% | 1.4 | 0.96 | 1.6 | 1.5 | |
| **$P_2O_5$ (kg $ha^{-1}$)** | | | | | |
| 20 | 7.1 | 8.0 | 15.8 | 10.3 | 10.30 |
| 40 | 8.3 | 8.7 | 16.3 | 12.3 | 11.40 |
| 60 | 8.0 | 8.5 | 16.3 | 12.7 | 10.99 |
| CD 5% | NS | NS | NS | 1.5 | |

Source : Chauhan *et al.,* 1988.

due probably to more salt build-up during rabi season.

It was concluded that 50% recommended dose of nitrogen (60 kg N $ha^{-1}$) with 15 t FYM $ha^{-1}$ during *rabi* proved quite economic giving seed yield to the tune of 20.8 q $ha^{-1}$ being higher by a margin of 246.6, 90.8, 46.4, 6.0 and 6.6% over control, 60, 90, 120 and 60 kg N $ha^{-1}$ with 5 t $ha^{-1}$ green manuring (*Sesbania*), respectively. Available nitrogen and organic contents were also increased in treatments with green manuring and organic matter.

All the chemical fertilizers are not equally effective on problem soils. In general fertilizers of acidic nature are advised on sodic and saline, sodic soils, as they help in bringing down soil pH, whereas on saline soils ammonical fertilizers are useful. Some of the effective and efficient fertilizers are given below.

**Table 7. Effect of nitrogen levels and organic matter on green fodder yield of sorghum and seed yield of Indian mustard following poor quality water (ECw 12 dS.m$^{-1}$ and SARw 10 meq L$^{-1}$)**

| Treatments | | Yield q ha$^{-1}$ | |
|---|---|---|---|
| *Kharif* | *Rabi* | Sorghum | Indian mustard |
| N0 nitrogen (Control) | Control | 1.78 | 6.0 |
| 30 kg N (50% RND) | 60 kg N (50% RND) | 2.18 | 10.9 |
| 45 kg N (75% RND) | 90 kg N (75% RND) | 2.47 | 14.2 |
| 60 kg N (100% RND) | 120 kg N (100% RND) | 2.76 | 19.6 |
| 75 kg N (125% RND) | 150 kg N (125% RND) | 2.94 | 21.6 |
| 30 kg N | 60 kg N + GM @ 5 t ha$^{-1}$ (*Sesbania*) | 2.62 | 19.5 |
| 30 kg N | 60 kg N + OM @ 15 t ha$^{-1}$ FYM | 3.02 | 20.8 |
| CD 5% | | 3.6 | 2.3 |

Average of 6 years (1990-91 to 1995-96): RND, recommended dose.
Source: Progress Report 1994-96, ICAR Coordinated Research Project, Management of Salt Affected Soils and Use of Saline Water in Agriculture, CSSRI, Karnal.

*Saline conditions*

- **N-fertilizers**: Ammonium sulphate, Calcium ammonium nitrate. (Silberbush *et al.*, 1985)
- **P-fertilizers**: Triple super phosphate, Super phosphate.

*Sodic conditions* :

- **N-fertilizers**: Ammonium sulphate, Calcium ammonium nitrate (Chhabra, 1982).
- **P-fertilizers**: Diammonium phosphate.

Saline-sodic conditions

- **N-fertilizers**: Diammonium phosphate, Ammonium sulphate.
- **P-fertilizers**: Triple super phosphate, Diammonium phosphate.

Efficiency of most commonly used N-fertilizer like, urea, can however, be increased by using neem cake treated urea and its granular forms. Similarly, sulphur

| Table 8. Tolerant and sensitive growth stages of oilseeds | | |
|---|---|---|
| Crop | Sensitive stages | Tolerant stages |
| Rapeseed mustard | Seedling emergence | Flowering to pod formation |
| Groundnut | Emergence to pegging stage | Pod formation to maturity |
| Safflower | Seed germination and seedling growth | Flowering to maturity |
| Sesame | Germination to maturity | – |
| Sunflower | Seedling stage | Seed germination |
| Linseed | Seedling stage | – |
| Castor | Seed germination | – |

coated urea is recommended for submerged saline areas of coastal soil belts due to its slow release and high uptake (Vishwas, 1982)

## Irrigation Management

Management of poor quality irrigation water needs utmost care and will depend on some basic facts, like, methods of irrigation, pre-sowing irrigation and its substitution, avoidance of irrigation at the critical sensitive growth stages and finally the depth and frequency of irrigation.

Furrow system of irrigation helps in monitoring low salt content in the root zone, is, therefore, preferred over flat system. Consumptive use of water is increased in this system indicating, thereby, leaching of salts is furrows.

Irrigation through sprinkler system on a sodic soil resulted in greater downward movement of soluble salts, higher water use efficiency; and *rapa* crop yields were more than with flood and ridge and furrow systems (Yadav and Girdhar, 1977). Ridge and furrow system is better over flood irrigation system which should be avoided under saline water irrigation. In a recent study also on sandy loam soils of Karanpur village (Mathura), sprinkler irrigation system gave almost 20 to 30% higher seed yield of mustard over flood irrigation (Anonymous, 1996).

Pre-sowing irrigation with either saline or sodic water has been observed very critical for all the oilseeds. Therefore, in order to enhance emergence potential of the seedlings, it is advised to apply presowing irrigation with good quality irrigation

**Table 9. Seed yield and water use efficiency (WUE) of Indian mustard on partially reclaimed soils (pH 8.8) under different soil moisture regimes at Karnal**

| Irrigation schedule | Seed yield (kg $ha^{-1}$) | WUE (kg $ha^{-1}$ $mm^{-1}$) |
|---|---|---|
| Unirrigated | 260 | 1.43 |
| One irrigation (R) | 900 | 3.27 |
| One irrigation (S) | 650 | 2.69 |
| Two irrigations (R + S) | 980 | 3.23 |
| 75 mm CPE | 1080 | 3.22 |
| 100 mm CPE | 960 | 3.32 |
| 150 mm CPE | 680 | 2.90 |
| CD 5% | 200 | – |

R, Rosette stage (30-40 DAS); S, siliquae formation (50-60 DAS).
Source: Annual Progress Report, CSSRI, Karnal, 1988.

water from the secondary source (Kumar and Kumar, 1990; Minhas *et al., 1990).*

In case of problem water being the only source of irrigation, pre-sowing irrigation 1-2 mm more than in normal case, must be applied to enhance temporary leaching of salts till the seedlings emerge out. Under sodic conditions, where early drying and clods formation hamper seedling emergence, irrigation must be heavy to the extent upper surface remains wet till the germination occurs. Continious wetting of upper surface will enhance and quicken the emergence. In case of quite poor emergence first irrigation can be advanced by 5-8 days.

Oilseed crops differ in their tolerance to saline water at growth stages, hence irrigation at these stages may be substituted or avoided and given at the tolerant stages. Sensitive and tolerant stages of oilseed crops to saline/sodic waters are given in Table 8 (Kumar 1994, 1995).

*Irrigation in quick succession or oth*erwise with medium interval before the drying of soil will essentially keep the salts away from the active root zone. In general irrigation 25% higher of the CPE is advised with moderate saline water for effective leaching of the salts.

Substitution of good quality water for saline water at the critical sensitive stage and the use of saline water at the appropriate tolerant stage is an important strategy for saline water management. Germination and early seedling growth are generally considered the most sensitive stages to saline irrigation and failure during these stages will consequently lead to drastic reduction in seed yields (Hamdy *et al.*, 1993). Brassicas, for that matter, are highly susceptible to saline waters (ECw 6 dS.m$^{-1}$) during emergence and seedling growth (Minhas *et al.*, 1990, He and Crammer, 1993 a,b,c). For instance, 6 year study at Agra revealed that seed yield of *B. juncea* (cv. Prakash, Pusa Bold and Varuna) were decreased by 50% following saline water irrigation (ECw 16 dS.m$^{-1}$) at presowing. However, saline water of the same concentration when applied at the secondary branches, enhanced yield by 16% (Kumar and Kumar, 1990). Thus, substitution of highly saline water to good water is feasible and rewarding at seedling emergence stage. Similarly, when saline water (ECw 12.3 dS.m$^{-1}$) was substituted by non-saline water, the maximum improvement in seed yield of Indian mustard was due to substitution at presowing (32%), followed by siliquae development (10%) compared to when saline water was applied throughout the cropping period (Minhas *et al.*, 1990).

Restriction of saline irrigation water is another approach of water management which prevents early build-up of salinity in the upper surface of soil and therefore, ensures sufficient growth and development. Experiments at Karnal on partially reclaimed soils (pH 8.8), revealed that one irrigation on the basis of 75 CPE proved sufficient (Table 9) to obtain optimum yield (1080 kg ha$^{-1}$) or one irrigation at rosette stage (900 kg ha$^{-1}$) vis-a-vis one irrigation at siliquae formation (650 kg ha$^{-1}$) and two irrigations at the aforesaid stages (980 kg ha$^{-1}$). Moreover, water use efficiency was also maximum with one irrigation at rosette stage or at the 100 CPE.

**Table 10. Some specfic growth and adaptive traits associated with annual oilseeds**

| Crop | Growth traits | Adaptive traits | References |
|---|---|---|---|
| Castor | Generally 50% yield declines at ECw 8 dS.m$^{-1}$, 50-60 meq salts L$^{-1}$ | Roots retain more sodium than leaves. Petioles contain large amount of sodium and chloride ions. | Ahmed *et al.*, 1978. Kumar *et al.*, 1989. Jeschke & Pate, 1991 |
| Linseed | Generally significant decline in seed yield observed at 60-100 mg salt L$^{-1}$ and 12 mg boron L$^{-1}$ | Affinity to tolerate moderate salinity and RSC waters. Prone to low levels of boron (3.5 - 3.6 mg L$^{-1}$) in sandy loam soils | Singh & Singh, 1991 Heikal *et al.*, 1980 Chauhan *et al.*, 1984. |

(Contd.)

(Contd.. Table 10)

| Crop | Growth traits | Adaptive traits | References |
|---|---|---|---|
| Peanuts | Generally significant decline in seed yield starts at NaCl ECw 2.5-3.5 dS.m$^{-1}$ and ESP 15-20. | Moderately sensitive to salinity and highly susceptible to sodicity. Sensitivity due to reproductive organs, $Na_2SO_4$ salts are more toxic. | Singh and Abrol, 1985. Nautiyal *et al.*, 1989. |
| Rapeseed and mustard | Significant decline in seed yield starts at ECw 8 dS.m$^{-1}$ and ESP 35-40. | Susceptible to seedling emergence but fairly tolerant to later growth stages | He and Crammer, 1993 b & c Kumar, 1994.) |
| *Chitti sarson* | Generally 50% decline in seed yield starts at ECw 10 dS.m$^{-1}$ | Better salt tolerant to Indian mustard | Anonymous, 1996. |
| Safflower | Emergence reduced and delayed at 75 mM NaCl and ESP 20, 50% decline in seed yield observed at ECw 10-12 dS.m$^{-1}$ | Susceptible to seedling emergence but highly tolerant at later growth stages. Generally more prone towards sodicity than salinity. Moderately tolerant to sea water (15000-20000 ppm with Horgalnd solution) | Goswami, 1978. Kurian and Iyengar, 1972. |
| Sesame | Yield starts declining at ECw 2.5 dS.m$^{-1}$, ESP 15 | Senstive to salinity and sodicity, better tolerant to mixture of salts but susceptible to single salts, calcium salts more detrimental than sodium salt | Nassery *et al.*, 1979 |
| Niger | Seedling emergence declines at ECw 0.03-3.6 dS.m$^{-1}$. | Moderately sensitive to moderate salinity levels but tolerant to boron | Abebe *et al.*, 1980. |
| Sunflower | Generally 50% reduction in germination starts at ECw 8.5-9 dS.m$^{-1}$ seed yield decreases significantly at ESP 24. | Moderately tolerant to salinity but more sensitive to sodicity. It can extract 2 to 2.4 times more Na followed by Cl and $SO_4$ than salt tolerant crops like, cotton and sugarbeet. Sunflower therefore, has biological salt management potential. | Bhatt & Indirakutty, 1973 El-Kobbia and El-Nennah, 1980 |

## SPECIFIC ADAPTATION

Oilseeds form a complex group of crops, which are morphologically much distinct and are cultivated under varied input and ecological needs. These crops have, therefore, developed specific adaptive and morpho-physiological features making certain species more suited to aberrant saline situations. The positive responses and different affinity to particular saline situations can be of theoretical and practical relevance in enhancing oilseeds productivity in reference to abiotic constraints. For instance, sunflower can be used as a means of biological reclamation of salts. Sesame is more tolerant to mixture of salts but sensitive to single salts. These are therefore, some important aspects in salt management strategy. Such information in respect of the annual oilseeds compiled from different sources is given in Table 10.

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