Fertigation
In
Indian mustard

Directorate of Rapeseed-Mustard Research
(Indian Council of Agricultural Research)
Sewar, Bharatpur 321 303, Rajasthan India

Printed :	July 2014
Citation :	Rathore S S, Kapila Shekhawat, O P Premi, B K kandpal and Dhiraj Singh 2014. Fertigation in Indian Mustard Directorate of Rapeseed-Mustard Research Sewar, Bharatpur-321 303 (Rajasthan) India pp 36
Compiled & Edited by:	Drs S S Rathore, Kapila Shekhawat, O P Premi, B K kandpal and Dhiraj Singh
Copyright :	Director Directorate of Rapeseed-Mustard Research Sewar, Bharatpur- 321 303 (Rajasthan), India
Published by :	Dr Dhiraj Singh Director Directorate of Rapeseed-Mustard Research Sewar, Bharatpur- 321 303 (Rajasthan), India Phone : +91-5644-260379, 260495 Fax : +91-5644-260565, 260419 e-mail : director.drmr@gmail.com Web : http://www.drmr.res.in
Printed at :	**Premier Printing Press** 12, Ram Nagar, Hawa Sarak, Sodala, Jaipur Phone : 0141-2294887, www.premierpress.in E-mail : offsetpremier@gmail.com

प्रो. स्वपन कुमार दत्ता
उपमहानिदेशक (फसल विज्ञान)
Prof. Swapan Kumar Datta
Deputy Director General
(Crop Science)

भारतीय कृषि अनुसंधान परिषद्
कृषि भवन, डा. राजेन्द्र प्रसाद मार्ग, नई दिल्ली – 110001
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI BHAWAN, DR. RAJENDRA PRASAD ROAD, NEW DELHI-110001

FOREWORD

Efficient nutrient management is vital for realization of sustainable high mustard productivity in India. Rapeseed-mustard productivity enhancement is a prerequisite for reducing dependence on import of edible oils. The increasing nutrient imbalance in major mustard growing areas of the country is a serious threat for sustaining high productivity. Precise delivery of the plant nutrients through fertigation in the crop root zone as per the crop requirement enhances the nutrient and water use efficiency up to 80 to 90%. The application of water soluble fertilizers along with micro irrigation systems is also useful in labour saving and improving partial and total factor productivity. The low nutrient use efficiency in conventional fertilizer application methods leads to wastage and environmental pollution. In this regards, fertigation with whole technological package can check the nutrient imbalance with existing rate of fertilizer application. Fertigation with micro irrigation has become the need of the hour to realize the ultimate goal of more crops per drop as envisioned by Hon'ble Prime Minister of India, Sh. Narendra Modi. This calls up on the need to follow, practice, and popularize the efficient nutrient management techniques among the farmers for achieving overall sustainability in Indian mustard production system. In the present time of increasing fiscal deficit due to subsidy, the loss of important subsidized agri-input (fertilizers) could be prevented to greater extent by adoption of location specific suitable fertigation system. This bulletin "Fertigation in Indian mustard" describing various aspects of fertigation and its effect on Indian mustard is timely and well conceived.

I am persuaded that this bulletin will help the rapeseed-mustard growers, academicians and researchers to understand and adopt fertigation and micro irrigation effectively. I compliment the efforts of Dr Dhiraj Singh, Director, DRMR and Drs S. S. Rathore, Kapila Shekhawat, O. P. Premi and B. K. Kandpal for compiling the information and bringing out this important publication.

Date : 04.08.2014
Place : New Delhi

(Swapan K Datta)

Preface

Increasing soil nutrient imbalance has become serious threat in achieving higher productivity in major mustard growing areas of the country. Efficient nutrient management, thus, is a very crucial managerial input for realization of sustainable higher mustard productivity. Fertigation through micro irrigation could be a potential approach for enhancing nutrient and water use efficiency. The nutrient and water use efficiency increases up to 90% through fertigation due to precise delivery of the plant nutrients in the crop root zone as per the crop requirement. The fertigation of water soluble fertilizers with micro irrigation systems lead to savings of labour, enhancing partial and total factor productivity and efficient delivery of chemicals including the use of fungicides and insecticides etc. This necessitates practicing, and popularizing the efficient nutrient management techniques amongst the farmers for realizing sustainability in Indian mustard production systems.

It is of utmost importance to have information on fertigation about suitable fertilizers containing major and micro nutrients, their probable combinations, devices for fertigation, precaution to be adopted for successful fertigation and response of Indian mustard to them. The present publication attempts to provide information on various aspects of fertigation in Indian mustard.

We are grateful to Deputy Director General (Crop Sciences), ICAR, New Delhi for his valuable guidance and accepting our request to write the foreword. We also place our sincere thanks to Director, DRMR for providing all support to finalize the manuscript. We anticipate this publication will help mustard growers, researchers, extension personnel and academicians in a wide scale adoption of fertigation. The suggestion and comments for its improvement are welcome.

Authors

DRMR, Bharatpur

August 5, 2014

CONTENTS

1

Introduction

Rapeseed-mustard is one of the most important oilseed crop of India which is grown on an area of about 6.5 million hectares (Mha) with 8.2 million tonnes (Mt) total production and 1262 kg/ha national average productivity. Almost 75% area under rapeseed-mustard is irrigated, which requires at least 1.2-2.0 million liters of water per ha for recommended two flood irrigations at 35 and 70 days after sowing. Up to 50% of irrigation water could be saved through micro-irrigation and the remaining quantity of water could be utilized for further intensification of cropping system. Fertigation with micro irrigation is becoming the need of the hour to realize the ultimate goal of more crops per drop. The task force on micro-irrigation has stated that 4.9 Mha is the potential area of edible oilseeds which might be brought under micro-irrigation. Fertigation is a method of fertilizer application in which fertilizers are incorporated within the irrigation water by any pressurized irrigation system, including the drip and sprinkler irrigation system. Fertigation precisely delivers the plant nutrients through irrigation system in the crop root zone as per the crop requirement. The application of water soluble fertilizer along with irrigation water is popularizing with micro irrigation systems for the advantages like labour saving, enhancing nutrient and water use efficiency, which results in higher partial and total factor productivity. The availability of nutrients is very high and uniform under fertigation therefore, the efficiency improves up to 80 to 90%. Fertigation is the agro-technique, combining water and fertilizer application providing a tremendous opportunity to maximize yield and minimize environmental pollution. Both liquid fertilizers as well as water soluble fertilizers can be successfully used for fertigation. In this background, the detailed information regarding the effect of fertigation and micro irrigation on growth, yield attributes, seed yield, economics, crop responses to the enhanced fertilizer supply through fertigation by Indian mustard under semi arid conditions is lacking. In this bulletin, the information on various facets of fertigation as suitable devices, fertilizers and their combinations, advantage and response of Indian mustard to fertigation and micro irrigation under semi arid conditions has been compiled.

Need of fertigation

Rapeseed-mustard is an energy rich crop and the requirements of major nutrients including secondary and micronutrients are high. In general, the estimated nutrient removal from the Indian arable soil is as high as 34 Mt per annum as against the estimated fertilizer consumption of 27.7 Mt, thus leaving a negative balance of 6.3 Mt. The current fertilizer consumption ratio is 8.2 : 3.2 : 1, while the optimum is 4:2:1. This indicates erratic and imbalance fertilizer use. Annual loss of nutrients through various degradation processes has been estimated to be between 5.37 and 8.4 Mt (Tiwari, 2008). In Major mustard growing areas of the country there is increasing trend of nutrient imbalance which is a serious threat for sustaining high mustard productivity (Table1). It shows that nutrient removal is more than their additions, which means this is an important reason for low productivity. The nutrient balance cannot be ensured with increasing the levels of fertilizers, as low nutrient use efficiency will lead to their wastage and subsequently environmental pollution. Thus, there is a need to explore new method of fertilizer application and in this regards, fertigation with whole technological package as per the response of Indian mustard under agro climatic condition can check the increasing trend of nutrient imbalance with existing rate of fertilizer application.

Table 1. Annual soil nutrient balance (.000 tonnes) in major mustard growing areas.

State	N	P_2O_5	K_2O	Total	Reference
Rajasthan	- 288	- 88	- 1061	- 256	Tandon (2004)
Punjab	- 5	0	- 7	- 12	Aulakh and Bahl, 2001
Haryana	- 23	- 92	- 480	- 595	Kumar *et al.*, 2001
Uttar Pradesh	- 6.8	- 0.06	- 56	- 63	Pal *et al.*, 2001
Bihar	+ 137	+ 49	- 438	- 252	Mishra *et al.*, 2001
Madhya Pradesh	- 18	- 87	- 825	- 929	Swaroop *et al.*, 2001
India	+ 1062	- 1741	- 5119	- 5798	

Indian mustard removes approximately 128.4 kg of N, 41-42 kg P_2O_5 and 106-108 kg of K_2O for producing 2000 kg/ha seed yield and with recommended dose of 80 kg N/ ha under irrigated conditions. By considering 40% of NUE, only 32 kg of N could only be utilized by the mustard crop from applied fertilizers sources. The remaining quantity of N is removed through mining of native soil N reserve leaving a huge nutrient imbalance. This calls up on the need to follow, practice, and popularize the efficient nutrient management techniques among the farmers for achieving overall sustainability in Indian mustard production system.

Benefits of fertigation in Indian mustard

• Water saving

Fertigation is generally done with micro irrigation system. And micro irrigation enhances the irrigation water use efficiency up to 90%. The irrigation scheduling under micro irrigation is done in such a manner to meet the crop evapo-transpirational demand. Losses through seepage, percolation and run off are minimized. The water under fertigation is supplied through the pipes than through open channels, thus the conveyance, application and evaporation losses are minimum. Along with the efficient delivery, up to 50% water saving has been reported through fertigation.

• Yield and quality improvement

Mustard yield under fertigation substantially improves over the conventional methods. Under micro-irrigation the availability of water and nutrients is very close to the root zone at a required time interval in the adequate quantity. The main reasons for higher yield under fertigation is that, unlikely conventional methods, it supplies water at regular intervals in the root zones of mustard plant. The water is supplied in small quantities, thus the plant does not suffer due to excess water or water stress during large intervals of irrigation. The soil moisture remains close to field capacity during the entire crop growth. Drip and micro-irrigation methods does not allow much weed growth, which ultimately helps to increase the yield levels.

• Enhancing nutrient use efficiency

The frequent applications in small doses not only increase availability but also reduce nutrient losses from soil surface. The reduced time fluctuation in nutrient concentrations in soil in the course of growing season in fertigation saves nutrient from leaching and percolating beyond the root zone. Fertigation helps in better distribution and higher uniformity of plant nutrients throughout the entire root zone or soil profile. The flexibility with fertigation helps in easy adaptation of the amounts and concentrations of specific nutrients to crop requirements, stages & climatic conditions. To enhance fertilizer use efficiency through application of nutrients accurately and uniformly, application according to the amounts and concentrations to plant needs

& climate, increases the availability and uptake of nutrients and reduces of nutrient losses from leaching, volatilization, fixation etc.

• Energy saving

Fertigation reduces the amount of electricity consumption by reducing the number of working hours of pump set. Also, the heavy machinery for making bunds, checks and lifting water from deep bores. Heavy farm machinery is not required this avoids soil compaction, maintain better soil physical conditions.

• Reducing cost of cultivation and improving B:C ratio

The fertigation system is mechanized which comparatively less labour for various farm operations need like fertilizer, pesticides application, tillage, weeding etc. As water and fertilizer are supplied evenly to the crops through fertigation there is possibility for getting 25-50 per cent higher yield. The amount of water saved through micro irrigation and fertigation may be utilized for growing of more crops per unit area and availability of water. The productivity and profitability is maximized through steady higher yield and quality produce, higher oil output and saving of irrigation water and over all low cost of operation. Fertilizer use efficiency through fertigation ranges between 80-90 per cent, which helps to save a minimum of 25 per cent of nutrients and saves time, labour and energy.

• To decrease the environment pollution

The increase in fertilizer use efficiency minimizes the wastage of fertilizers in the form of their release in the environment. The NO_3 pollution of groundwater can be minimized by better uptake and utilization of N in the plant system. The eutro-fication is one of the main environmental problems due to misused of fertilizers which are reduced to a significant level through fertigation.

• Uniformity in application

Fertigation through micro irrigation occur at a predetermined rate and pressure. The quantity of fertilizer and water can be regulated in such a manner so that uniformity of fertilizer application can be maintained at tail end of the field. This helps in better fertilizer management in the field.

- **Recharge of ground water**

Micro irrigation and fertigation on integration with water harvesting through a holistic approach of water shed management ensure not only saving of precious water resources but also leads to better recharge of ground water.

- **Problematic soils:**

Fertigation maintains proper nutrient level in root zone thus enabling farming in marginal soils having low CEC & low fertility status.

- **Operation is fast and convenient**

Full control over the process allows application of micronutrients thus avoiding need for separate foliar application. It remains unaffected by wind and causes no runoff. The fertigation system is not only simple and convenient but also deliver nutrients and water are supplied near the active root zone through release of nutrient which results in greater absorption by the crops.

2

Fertigation Versus Soil Fertilization

In India total fertilizers consumption was 27.7 Mt, comprising 17.3 Mt N, 7.9 Mt P and 2.6 Mt of K fertilizers. Of the total fertilizers consumed in our country (27.7 Mt) almost 45 % is being imported, thus involves huge foreign exchange. The conventional methods of fertilizer application includes broadcasting, top dressing through spraying, soil application through seed-cum-ferti drill in planting rows, which waste massive quantity of fertilizers. In fertigation, fertilizers are only supplied along with water; the leaching of fertilizers is substantially reduced compared to conventional methods like basal and top dressing which enhances nutrient use efficiency (table 2). The losses through soil application of major and micro nutrients are enormous which have many ramifications on whole agricultural production system. In the present time of increasing fiscal deficit due to subsidy the loss of important agri input (fertilizers) could be prevented to greater extent by adoption of location and crop specific suitable fertigation system. This is the urgent requirement to be met for achieving the goal of sustainable agriculture and for over all vibrant economy.

Table 2. Fertilizer use efficiency of various nutrients under different application methods.

Nutrient	Fertilizer use efficiency (%)	
	Soil application	Fertigation
Nitrogen	30-50	90-95
Phosphorous	15-20	45-50
Potassium	50-60	70-80

3
Devices for fertigation through micro irrigation system

There are various devices developed based up on their suitability on available pressure, head, economics, crop and fertilizer to be used for fertigation with pressurized irrigation systems.

(A) Ventury Injectors

It is one of the easiest and cheap devices for fertigation and it works on the basis of pressure difference by sucking the liquid fertilizers from designated structure. The main limitation of the ventury injector is that it reduces pressure, thereby discharge of water which results in coverage of less area per unit of time. As the pressure is optimized manually to facilitate the sucking of fertilizers, this may sometimes lead to collapse main line, if proper care is not taken. The other features of the ventury are as follows:

- Fertilizer and chemical injection through drip and sprinkler irrigation systems.
- Excellent chemical resistance to most of the chemicals.
- Economical and low cost option.
- Delivers plant nutrients directly into the wetted zone (where root development is intensive) at uniform rate
- In-built check valve for protecting the injected liquid against back flow
- Can be used with a large variety of chemicals
- Uniform application of fertilizers
- Saves Energy & Manpower
- Needs less pressure

Fig 1.ventury A. attached with main line, B. Single unit

(B) Fertilizers Injector Pump

The fertilizer injector pumps are recommended to use where precise application of fertilizer and other agro-chemicals are required. These are used to inject the fertilizer solution from a supply tank into the line. Injection energy is provided by hydraulic motors. Strong plastic material with high chemical resistance and compact design should be selected for making these pumps to ensure accurate and proportional injection rate. The rate can be set externally to the desired percentage as per the crop requirement. These pumps are very simple to install, operate and maintain.

Fig 2. Fertilizers injector pump

(C) Fertilizer Tank

Fertilizer tanks work on the principle of differential pressure created by a valve, pressure regulation by fractionin the main line.

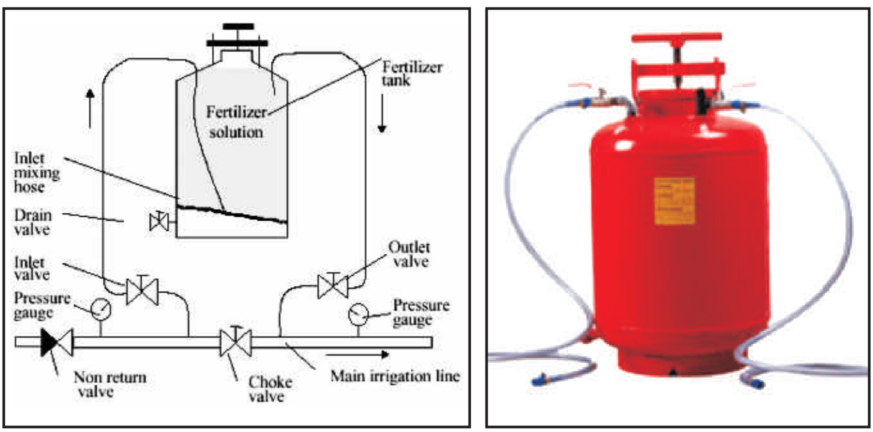


Fig 3. Fertilizer tank along with other associated devices

The pressure difference forces the water to enter through a by-pass in to a pressure tank which contains fertilizer and to recirculate with varing amount of dissolved fertilizer. The material selected should be anti corrosive coated with more than 70 micron thick deep blue coloured epoxy powder from both inside and outside surface for protection against corrosion and weather effects. Although, it delivers fertilizers even at low pressure, range is between 1 to 6 kg/cm2, maximum being 10 kg/cm² (142 psi). Fertilizers are delivered directly into the root zone on quantitative basis. Tumultuous inlet ensures thorough mixing of chemicals and / or fertilizers. Separate valves are also provided on the inlet & outlet to control the injection rate. The cost of various fertigation devices has been given in Table 3.

Table 3. The cost of different fertigation devices

Sl.No.	Fertigation devices	Cost (Rs.)
1.	Ventury type	1200
2.	Fertilizer Tank	3000
3.	Injectors	12000

4

Fertilizers suitable for fertigation

It is essential to know the suitability of different fertilizers for fertigation. The characteristics features which determines the suitability of particular fertilizer depends upon its solubility, compatibility, corrosivity, nutrient content and the response to a specific crop. The solubility and compatibility of the particular fertilizer material is the main consideration for selection of the fertilizer. Fertilizer evaluation criterion is explained in table 4 for fertigation and graded their quality on the basis of Solubility precipitation, compatibility and corrosion .

Table 4. Fertilizer evaluation for suitability to fertigation

Property	NH_4NO_3	$(NH_4)_2SO_4$	K_2SO_4	KCl	KNO_3	H_3PO_4	MAP
Solubility	High	Medium	Low	Medium	Medium	High	Medium
Precipitaion	Low	High	High	Low	Low	Low	Medium
Compatibility	Good	Poor	Poor	Medium	Medium	Medium	Good
Corrosion	Medium	Poor	Poor	Poor	Good	Poor	Medium

The following characteristics of fertilizers are preferred for fertigation:

- The fertilizer should have high nutrient content in a readily available form to plants.
- It should be fully soluble in irrigation water at field temperature conditions with low content of insolubles (< 0.02%).
- It should be flowable having fine grade with minimum content of conditioning agents.
- It should be compatible with other fertilizers, should not cause any clogging of filters and emmiters.
- It should have minimal interaction with irrigation water and does not change drastically the water pH.
- It should have low corrosivity for the system.

Generally, urea, potash and highly water soluble fertilizers are available for applying through fertigation. Application of super phosphorus through fertigation must be avoided as it makes precipitation of phosphate salts. Thus phosphoric acid is more suitable for fertigation as it is available in liquid form. Special customized fertilisers like mono ammonium phosphate (Nitrogen and Phosphorus), poly feed (Nitrogen, Phosphorus and Potassium), multi K (Nitrogen and Potassium), Potassium sulphate (Potassium and Sulphur) are highly suitable for fertigation as they are highly soluble in water. Fe, Mn, Zn, Cu, B, Mo can also be supplied along with special fertilisers. Various fertilizers of major and micro nutrient sources along with their composition suitable for fertigation described below.

Fertilizer sources of primary plant nutrient suitable for fertigation

Nitrogen is the main element applied through fertigation due to the fact that urea is the main source of N application and it is highly soluble in water. There are certain other nitrogenous fertilizers (Table 5) suitable for fertigation, their grade, formula and suitable pH have been mentioned in the Table 5.

Table 5. Specific characteristic of Nitrogen fertilizers suitable for fertigation

Fertilizers	**Grade**	**Formula**	**pH (1 g/L at 20^{o}C)**
Urea	0	$CO(NH_2)_2$	5.8
Potassium nitrate	13 – 0 – 46	KNO_3	7.0
Ammonium sulfate	21 – 0 – 0	$(NH_4)_2SO_4$	5.5
Urea ammonium nitrate	32 – 0 – 0	$CO(NH_2)_2 . NH_4NO_3$	
Ammonium nitrate	34 – 0 – 0	NH_4NO_3	5.7
Mono ammonium phosphate	12 – 61 – 0	$NH_4H_2PO_4$	4.9
Calcium nitrate	15 – 0 – 0	$Ca(NO_3)_2$	5.8
Magnesium nitrate	11 – 0 – 0	$Mg(NO_3)_2$	5.4

Phosphorus is one of the main primary elements after nitrogen and generally applied as basal placement before sowing of the crop. It has been revealed by many researchers that good response was obtained on fertigation of phosphatic fertilizers on the crops. Not many fertilizers sources are available for fertigation , in table 6 suitable phosphatic fertilizers have been mentioned along with their grade and chemical formula.

Table 6. Specific characteristic of phosphatic fertilizers suitable for fertigation

Fertilizers	**Grade**	**Formula**	**pH (1 g/L at 20°C)**
Phosphoric acid	0 – 52 – 0	H_3PO_4	2.6
Monopotassium phosphate	0 – 52 – 34	KH_2PO_4	5.5
Mono ammonium phosphate	12 – 61 – 0	$NH_4H_2PO_4$	4.9

Indian soils were rich in potassium and due this fact in many crops there is no recommendation of Potash (K) . But continuous K mining from the soil has depleted the reserve soil potassium as also evident from the table 1; there exist huge net nutrient imbalance with respect to K in the soil. There is urgent need to meet the K requirement of the crop. The time has come to change the general perception of application of K only through basal placement. Good numbers of K fertilizers are available for fertigation which are explained in the Tabel 7.

Table 7. Characteristics of Potassium fertilizers suitable for fertigation

Fertilizers	Grade	Formula	pH (1 g/L at 20°C)	Other nutrients
Potassium chloride *	0 – 0 – 60	KCl	7.0	46 % Cl
Potassium nitrate	13 – 0 – 46	KNO_3	7.0	13 % N
Potassium sulfate #	0 – 0 – 50	K_2SO_4	3.7	18 % S
Potassium thiosulfate✱	0 – 0 – 25	$K_2S_2O_3$	5.5	17 % S
Monopotassium phosphate	0 – 52 – 34	KH_2PO_4	5.5	52 % P_2O_5
* Only White # Only Fertigation grade ✱ Liquid				

Recommended combinations of water soluble fertilizers

Use separate tanks for fertilizers that interact and cause precipitation. Ca, Mg & micro-nutrients should be placed in one tank and phosphorus and sulphate compounds in the other tank to enable safe and efficient fertigation

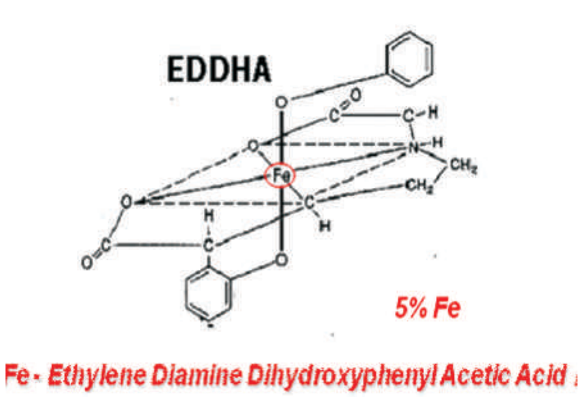
Fertilizer	Abbreviation	UR	AN	AS	MAP	NKP	PN	PN+Mg	PN+P	SOP	CN	$CaCl_2$	Mg+N
Urea	Ur												
Ammonium nitrate	AN	C											
Ammonium sulphate	AS	C	C										
Mono ammonium phosphate	MAP	C	C	C									
Mono potassium phosphate	MKP	C	C	C	C								
Multi K	PN	C	C	L	C	C							
Multi-KMg	PN+Mg	C	C	L	L	L	C						
Multi-NPK	PN+P	C	C	C	C	C	C	X					
Potassium sulphate	SOP	C	C	C	C	C	C	C	C				
Calcium nitrate	CN	C	C	L	X	X	C	C	X	L			
Cacium chloride	$CaCl_2$	C	C	L	X	X	C	C	X	L	C		
Magnisal	Mg+N	C	C	C	X	X	L	C	X	C	C	C	
Magnesium sulphate	MgS	C	C	C	X	X	L	C	X	C	L	L	C
C-Comaptible, L- Limited compatible, X- Incompatible													

Fig 4. The compatibility chart for water soluble fertilizers

Micronutrients used in fertigation

Most of the micro nutrient as inorganic salts of sulfates of Fe-Zn-Mn-Cu become rapidly unavailable in the soil due to their reaction with Ca and P and form precipitates in the irrigation laterals. This reduced availability of micro nutrients to crop plants and clogs the drippers and nozzle of sprinkler system. There is need to apply micro nutrients through chelates which prevent above negative effect.

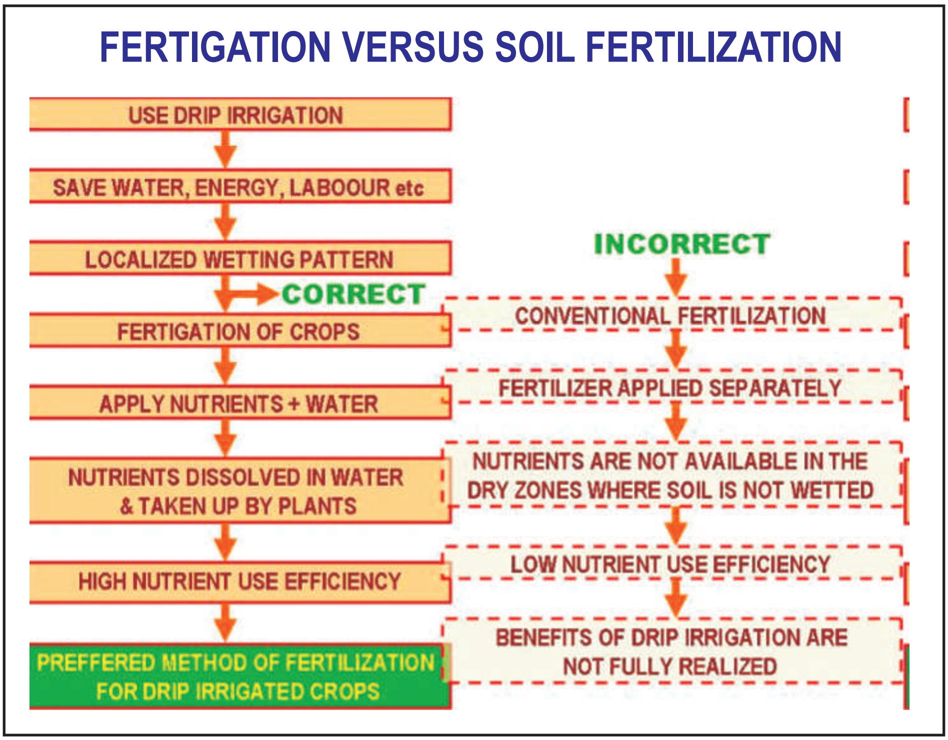
In fertigation the micro nutrients are being used as chelates, which are protective and stable organic molecule wrapping the metal. The chelates also avoid precipitation and hydrolysis. In Fig … shown the chelates of Fe with EDDHA as iron ethylene dihydroxyphenyl acetic acid.



A

B

Fig 5. A- chelates 5% Fe in EDDHA , B- chelates 9% Zn in EDTA



5

Response of Indian mustard to fertigation

The experiments on standardization of micro-irrigation and fertigation methods for mustard crop under semiarid conditions of Rajasthan was undertaken during *rabi* seasons of 2009-12 on 1.0 hectare area with 0.5 ha area each under micro-sprinkler and drip irrigation system along with fertigation system . The minimum pressure requirement to run 30 points of the micro irrigation and fertigation system is 2.5 kg/cm^2 under micro sprinkler system. The main line was of 75 mm, submain 63 mm and MIS lateral was of 32 mm in micro sprinkler system and the size (diameter) of drip laterals was 16 mm. The electric pump of 5.0 Hp (size 65 mm x 50 mm, head 30.0 mtrs, impearl diameter 173.0 mm, with a capacity range of 8.9-3.9 lps was used.

Fig. 6. A. Part circle micro-sprinkler head in action, B. fertigation system with hydrocyclone and disc filters

Micro-sprinkler, drip systems, and their combination with check basin methods resulted in significantly higher growth attributed like plant height, dry matter accumulation, and chlorophyll concentration as compared to check basin alone.

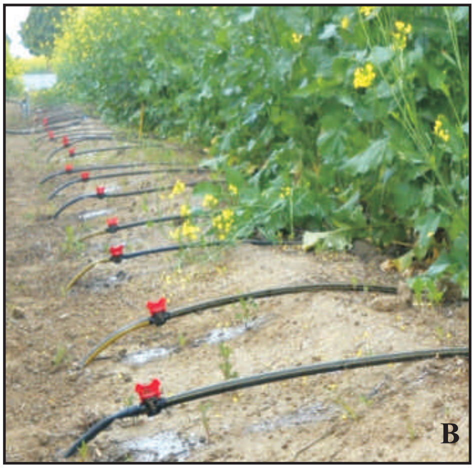


Fig 7. A. Drip lateral alongwith regulating valve, B. leteral in between mustard rows

The similar trend has been recorded for biological, seed and oil yield. Water use efficiency and production efficiency have been recorded highest in pressurized irrigation systems with fertigation. The irrigation water use efficiency and gross water use efficiency has been recorded highest under drip system being at par with the micro-sprinkler due to uniform moisture distribution in the soil profile. Fertigation of Indian mustard with nitrogen enhances the growth parameters and yield attributes with increasing dose of nitrogen up to 120 Kg/ha, while the days to 50% flowering reduced with higher N doses. The enhanced yield under 120 Kg N/ha also resulted in higher sustainability index, production efficiency and water use efficiency.

Growth parameters

Different micro-irrigation systems and fertigation of different doses of nitrogen significantly influenced plant height, dry matter accumulation, days to 50 % flowering and chlorophyll concentration in terms of SPAD value in mustard crop). Significantly higher plant height of mustard has been recorded under drip irrigation system. (Table 9).

The dry matter accumulation per plant has been recorded highest in the combination of micro-sprinkler and check basin method. The moisture distribution in the soil under micro-sprinkler method promotes better root proliferation and thus, the plant structure under micro-sprinkler was more vigorous than drip irrigation method with higher number of primary and secondary branches. The water application under micro irrigation coincides with the water requirement of the crops throughout the growth stages without causing any water stress. This results in better growth of mustard under micro irrigation system as compared to the check basin method. Days to 50% flowering were significantly higher for micro-irrigation as compared to check basin method due to 'stay-green' effect. Fertigation distribute nutrients and water through the drippers directly into the root zone of the plant, entering the soil through the combined forces of gravity and capillarity. This reduces the nutrient losses through volatilization and leaching.

Fig 8. Fertigation in Indian mustard at a. early stage (early seedling stage) b.later stage (flowering)

Differential chlorophyll levels (SPAD units)

The content of chlorophyll is a very important indicator of photosynthetic potential. The chlorophyll levels, as measured by the SPAD meter, have been recorded higher for drip system irrigated treatments as compared to check basin method. The SPAD units also increased with increasing N doses (Table 8). The higher SPAD units observed for drip and micro-sprinkler under higher N doses is likely associated with the more efficient N uptake efficiency and better photosynthetic leaf function, especially during late seed filling which may lead to a longer ''stay-green'' period, longer seed-fill interval and corresponding higher seed yield. Increasing levels of nitrogen also had direct effect on mustard plant height and maximum plant height was recorded under 120 Kg N/ha. Nitrogen is responsible for luxurious plant growth, more dry matter accumulation and uptake of other nutrients also. Days to 50% flowering reduced significantly with

N supply due to quicker phonological development, balance between vegetative and reproductive phases and optimum plant growth.

Different irrigation systems resulted in significant variation in commencement of flowering. Relatively early flowering was noticed under combination of micro-sprinkler and check basin. Maximum days to 50 % flowering were observed in micro-sprinkler during both the year. Fertigation of N doses recorded reverse trends in days to 50% flowering and minimum days were required with higher N levels (120 kg/ha). SPAD values gradually increase with higher levels of N fertigation. Nitrogen has direct role in synthesis of chlorophyll and due to this reason higher N levels resulted in better chlorophyll concentration and more SPAD value.

Yield attributes

Micro sprinkler and drip irrigation systems alone or with check basin results in better plant water status and the plant seldom faces water stress, which may be the reason for significant variation in response of yield attributes under micro irrigation systems as compared to the check basin alone. Maximum numbers of primary and secondary branches have been recorded under micro sprinkler and minimum number of branches (primary and secondary) have been recorded under check basin irrigation system. Main shoot length, which is an important mustard yield attribute, also followed the similar trend during both the years and has been significantly higher under MS over drip and combination of micro irrigation with check basin. Siliqua on main shoot was higher in drip irrigation system but on par with micro-sprinkler irrigation system. Total number of siliquae per plant was also recorded highest in the micro-sprinkler. Seeds per siliqua were in the range of 14-16 and maximum seeds per siliqua were recorded under the in micro-sprinkler with N fertigation (Table 9). Fig 9 shows the response of N fertigation to Indian mustard at full bloom stage.

Table 8: Growth parameters Indian mustard under micro-irrigation and fertigation

S.No.	Treatments	Plant height cm	Dry weight gm	Days to 50 % flowering	SPAD
Irrigation systems					
1	CB	197.9	45.7	59.55	43.80
2	DS	207.05	52.6	58.8	43.75
3	MS	190.1	57.1	60.75	43.65
	CD at 5%	10.0	6.6	1.25	NS

Fertigation of N (kg/ha)					
1	Control	184.6	37.2	63.6	36.60
2	N40	196.2	48.5	61.8	43.80
3	N80	202.25	60.2	57.55	46.00
4	N120	208.0	62.5	55.75	49.50
	CD at 5%	7.95	2.9	1.03	1.50

Fig 9. Indian mustard at full bloom stage under fertigation

Table 9: Yield attributes of Indian mustard under micro-irrigation and fertigation

S.No.	Treatments	No. of primary branches	No. of secondary branches	Main shoot length, cm	Siliqua on main shoot	Total siliqua /plant	Seeds/ siliqua	1000 seed weight	Harvest Index
Irrigation systems									
1	CB	5.30	7.00	77.50	61.00	171.55	14.40	4.60	0.26
2	DS	5.85	8.00	80.70	68.30	210.30	14.80	4.95	0.28
3	MS	6.00	9.25	87.15	66.55	230.40	15.75	5.10	0.25
	CD at 5%	1.20	1.70	6.35	4.15	23.90	0.95	0.40	0.05

Fertigation of N (kg/ha)									
1	Control	5.10	5.55	73.40	54.00	134.60	13.45	4.75	0.25
2	N40	5.45	8.00	80.60	63.65	191.80	14.95	4.85	0.26
3	N80	6.30	10.15	84.30	71.55	228.80	16.60	5.05	0.27
4	N120	6.25	9.80	85.05	68.65	274.40	15.60	4.95	0.26
	CD at 5%	0.82	1.20	4.45	4.30	25.25	0.65	0.22	0.02

1000 seed weight under micro-sprinkler being at par with all micro-irrigation treatments and significantly higher over check basin. The micro-sprinkler and drip system alone produced highest 1000 seed weight. The effect of various irrigation treatments on harvest index was inconsistent. The inconsistent behavior is due to the variations in the vegetative growth produced under the variable soil moisture and rainfall patterns. Increasing level of N fertigation from 0-120 kg/ha resulted in gradual increase in most of the yield attributes (Table 9). The N levels up to 80 kg/ha produced maximum number of primary branches, secondary branches, main shoot length, siliquae on main shoot, total siliquae per plant, 1000 seed weight and harvest index during 2009-10. Although, all the parameters increased with 120 kg N/ha but the response in general was at par with 80 kg N/ha.

Biological, seed and oil yield

Maximum biological, seed and oil yield have been harnessed from mustard grown under micro irrigation systems (Table 11). Maximum biological yield has been obtained under combination of micro-sprinkler and check basin method which was found at par with the micro-sprinkler alone. The highest biological yield was obtained by micro-sprinkler alone which was found at par with drip system and combination of micro-sprinkler and check basin. The benefits of micro irrigation may include better crop survival, minimal yield variability and improved crop quality. Several experiments have shown positive responses in most of the crops to high frequency drip irrigation (Fig. 10).

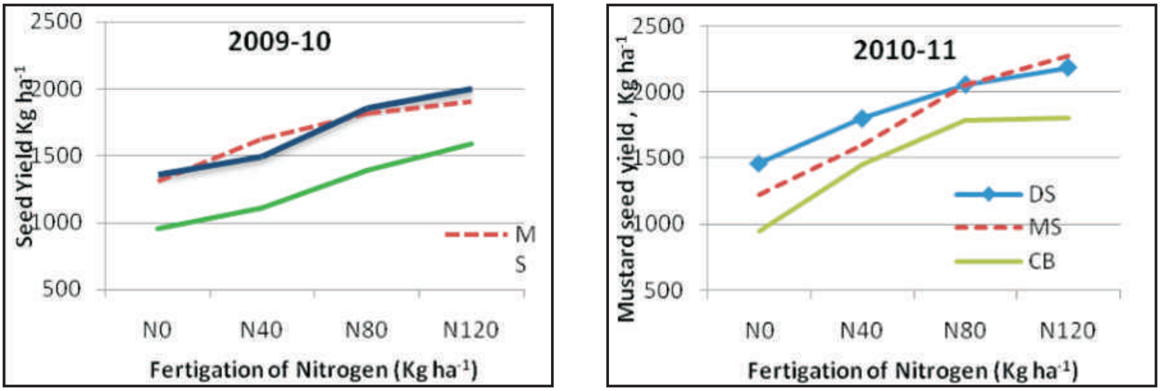


Fig 10: Seed yield of Indian mustard (Brassica juncea, Var-rohini) under different irrigation systems and N fertigation

Gradual increase in seed, biological and oil yield was recorded with the increase of N levels under fertigation and maximum seed, biological and oil yield was realized at 120 kg N/ha. The rate of increase was higher between first two doses as compared to 120 kg N/ha. The yield advantage is attributed to the improved efficiency of irrigation and nutrient use and reduces application costs through fertigation. It improves plant growth and nutrient uptake and limits nutrient losses (Table10).

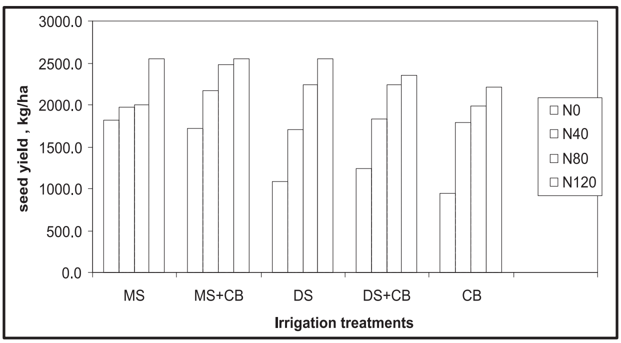


Fig 11: Interaction effect of irrigation systems with various levels of N fertigation on seed yield of Indian mustard (var: rohini)

The interaction of the seed yield obtained under various irrigation systems with the N doses indicates that at a given level of N, the yield obtained was higher for micro-sprinkler and drip system as compared to the check basin method (Fig.1). Amongst the two micro-irrigation systems, the response was higher for micro-sprinkler due to uniform water distribution in the soil profile.

For the similar response from drip system, the distribution of laterals within the rows must be standardized. In the given experiment, one lateral was laid after every 3 rows. The uniform moisture distribution helps in better growth, higher nutrient uptake and reducing losses which ultimately improves the yield. It can also be concluded that the crop response to applied nutrient can be enhanced by using micro-irrigation method. In check basin method, the nutrient loss occurs through leaching and runoff resulting in the higher fertility gradient within the same field.

Production efficiency

Significant variation in production efficiency was observed under various irrigation systems during both the years. Relatively higher production efficiency was recorded during 2010-11 over 2009-10 because of prevailing favourable weather conditions. Proper water management through micro-irrigation helps the crop in quick utilization of the readily available nutrients resulting in higher growth and dry matter accumulation which increases the per day productivity of mustard as compared to check basin method. Micro sprinkler irrigation system recorded maximum production efficiency during 2010-11, combination of micro sprinkler and check basin irrigation system being at par with it. Production efficiency increased with increasing levels of N/ha and maximum production efficiency was recorded at 120 kg N/ha during 2010-11 but statistically at par with 80 kg N/ha during 2009-10. Nitrogen supply to mustard improved the integrity of plant structure and key physiological processes such as light interception by chlorophyll, energy for carbohydrate build-up and enhanced the hydraulic conductivity of the root cortical cells, thereby improving the yield.

Economics

Over the years (2009-2011), the net returns and B:C ratio was estimated for different levels of N fertigation under various systems of irrigations. Both, the irrigation system and N fertigation levels significantly influenced the seed yield of mustard (Table 10 and Fig 1). The highest net returns and B: C ratio was recorded with micro sprinkler irrigation systems followed by DS alone and combination of MS with CB. An increment of 39.33% and 41.4 % was recorded in net return and B: C ratio respectively with MS irrigated Indian mustard over CB. Least B: C ratio and net returns was obtained under check basin irrigation (2.29 and Rs 28733 respectively).The higher above ground dry matter and subsequent higher assimilate supply was obtained under MS and DS over CB due to favorable soil moisture conditions. Likewise, increasing levels of N fertigation increases the productivity of Indian mustard. The net returns at 40 and 80 kg N /ha (Rs 34317 and 43430/ha respectively) were 41.03 % and 78.48 % higher respectively over control (Rs 24333.0/ha). The B: C ratio obtained under 40 and 80 kg N/ha was 3.48 and 2.75 respectively. However, the response beyond 80 kg N/ha was found at par in terms of both net return and B: C ratio (Table 10). With micro-sprinkler, the crop response can be obtained at higher levels of applied N, even up to 120 kg N/ha besides increasing the water use efficiency by two folds.

Indian mustard shows better response to fertigation and with the higher levels of fertilizer doses even better response in terms of nitrogen use efficiency and Agronomic NUE were recorded (Table 11 &12). The higher nutrient use efficiency led to higher mustard productivity.

Table 10: Effect of irrigation methods and fertigation on biological, seed and oil and irrigation water use efficiency, gross water use efficiency of Indian mustard (Cv Rohini)

S.No.	Treatments	Biological yield kg/ha	Seed Yield kg/ha	Oil yield kg/ha	Production efficiency (kg/ha/ day)	Irrigation water use efficiency, kg/ha-mm	Gross water use efficiency kg/ha-mm	B: C ratio	Net returns (10^3 Rs/ha)
Irrigation systems									
1	CB	6277.0	1509.5	498.5	9.7	12.7	8.5	2.29	28.73
2	DS	6775.5	1788.5	767.0	11.6	29.8	15.4	3.16	38.75
3	MS	7661.0	1873.0	786.0	12.25	31.3	16.1	3.23	40.04
	CD at 5%	830.0	214.4	48.9	1.45	2.1	1.4	0.9	2.56
Fertigation of N (kg/ha)									
1	Control	5533.0	1290.0	652.0	8.9	17.3	9.7	2.01	24.33
2	N40	6721.5	1652.0	666.5	10.75	21.7	12.2	2.75	34.32
3	N80	7569.0	1933.5	678.5	12.7	25.6	14.7	3.48	43.43
4	N120	8146.0	2111.5	818.0	13.15	27.8	513	3.49	45.63
	CD at 5%	442.0	81.5	50.0	1.05	1.9	1.6	1.2	2.65

Table 11: Nitrogen use efficiency (kg seed/kg N) under N fertigation and irrigation system

Levels of N kg/ha	MS	DS	CB
N 40	58.0	53.2	47.1
N 80	32.7	30.9	25.8
N 120	25.2	22.9	18.8

Table 12: Agronomic NUE under N fertigation and irrigation system of Indian mustard

Levels of N kg/ha	MS	DS	CB
N 40	11.2	11.2	13.1
N 80	8.6	9.9	8.8
N 120	10.0	8.9	7.4

6

Conclusion

To meet the ever-increasing demand of edible oils, agriculture must produce more with less water and fertilizer. It simply means there is high time to enhance nutrient and water use efficiency to maximum possible level. The use of pressurized irrigation technology could increase water use efficiency and reduce cost. With micro-sprinkler, the better crop response can be obtained with fertigation, besides increasing the water use efficiency by two folds. Indian mustard (Brassica juncea) is an important edible oilseed crop in Indian subcontinent and also in other tropical and subtropical regions. It is mainly grown under limited water availability conditions but is highly responsive for irrigation. The limited available water in semi-arid areas can be efficiently utilized through proper irrigation scheduling and fertigation under micro irrigation. The application of plant nutrients through fertigation has become practical. The response of the mustard for the applied nutrients can also be enhanced through micro irrigation systems. Fertigation is one of the major foundations for a plant growth and yield. Keeping accurate nutrient content is very important for optimal growth and maximum yield. Proper care is required in monitoring, keeping proportional fertigation and choosing the proper fertigation system.

6

Further reading

Allen R G, Pereira L S, Raes D and Smith M.1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO irrigation and Drainage Paper No. 56, FAO, Rome, Italy, p. 300.

Johnston A.E. 2003. Fertigation Fertilization through Irrigation. IPI Research Topics_No. 23. International Potash Institute ,Switzerland.

Rajput, T.B.S. And Neelam Patel. 2002. Fertigation Theory and Practices, Publication no. IARI/WTC/2002/2, 56p.

Sanjay Singh Rathore, Kapila Shekhawat, Basant Kumar Kandpal and Om Prakash Premi. 2014. Micro-irrigation and fertigation improves gas exchange, productivity traits and economics of Indian mustard (Brassica juncea L. Czernj and Cosson) under semi-arid conditions. AJCS 8(4):582-595 (2014) : 582-592.

Tandon, H.L.S. 1990. Fertilizer recommendations for oilseed crops- A Guide book. Fertilizer Develoment and Consultation Organisation, New Delhi.

Tandon, H.L.S. 2004. Fertilizers in Indian Agriculture – from 20th to 21st century. FDCO, New Delhi, India. pp. 240.

NOTES