Original Research Article

Effect of irrigation scheduling on nutrient uptake and soil microorganisms in linseed (*Linum usitatissimum* L.)

ABSTRACT

An investigation was carried out at Main Agriculture Research Station, Raichur, India, University of Agricultural Sciences, Raichur, Karnataka (India) during *rabi* 2023-24 to study the effect of irrigation scheduling in linseed on nutrient uptake and soil microorganisms. The results revealed that, pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) (T_4) recorded significantly higher nutrient uptake by linseed crop (46.07, 19.87 and 39.83 NPK kg ha^{-1}). The rainfed condition treatment (T_5) recorded significantly lower nutrient uptake by the crop (19.35, 8.15 and 18.40 NPK kg ha^{-1}). Among the different treatments, pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) recorded significantly higher soil microbial population of bacteria (16.1 X 10^6 cfu g^{-1} of soil), fungi (13.8 X 10^4 cfu g^{-1} of soil) and actinomycetes (6.8 X 10^3 cfu g^{-1} of soil) as compared to other treatments. The soil enzymatic activity was significantly influenced by scheduling of irrigation at different growth stages in linseed. At harvest among the different treatments, pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) recorded significantly higher dehydrogenase, urease and alkaline phosphatase activity (18.63 µg TPF g^{-1} soil day^{-1}, 22.5 µg NH_4-N g^{-1} soil hr^{-1} and 14.4 µg PNP g^{-1} soil hr^{-1}, respectively).

Keywords: Nutrient uptake, Nitrogen, Phosphorus, Potassium, Microorganisms, Fungi, Bacteria, Actinomycetes, Enzyme activity.

INTRODUCTION

Land and water are the two basic requirements for progress in agricultural productivity and economic prosperity of the country. Though land is also a constraint, there is scope for utilizing the same in an intensified manner by enhancing the cropping intensity in the cultivated area to achieve more production targets. The demand for these two resources is continuously increasing. Since, the country has to feed its growing population, scientists have already assessed that water is going to be a major natural resource constraint in enhancing the agricultural production. Further, the cultivation area can also be increased by utilizing the fallow and uncultivated lands, but this is not possible in case of water. Water is the major input for agriculture. Rainfall directly or indirectly influences the availability of water resources like underground water and surface water over a particular area.

Unscrupulous usage of surface water reserves and over exploitation of subterranean aquifer storage has resulted in a precarious situation of mining the “Liquid gold – Water”. Majority of our crops require irrigation through which water needs to be supplied to the crop rhizosphere in order to replenish the soil moisture deficit and to maintain a favourable soil moisture tension [4].

Linseed occupies an area of 32.23 lakh ha yielding 30.68 lakh tonnes with an average productivity of 952 kg ha^{-1} in the world. Whereas in India, it occupies an area of 2.39 lakh ha with a production and productivity of about 1.67 lakh tonnes and 698 kg ha^{-1}, respectively. India holds fifth position in area and ranks sixth in production [1]. Though there has been slight improvement in average productivity over the previous years, but it is still far below than the potential yield (2000-2200 kg ha^{-1}) of improved linseed varieties in the major linseed growing nations such as Canada (1432 kg ha^{-1}), China (1308 kg ha^{-1}), USA (1258 kg ha^{-1}) and Kazakhistan (809 kg ha^{-1}) underlying the need for upscaling the production and productivity of this crop. The present status of linseed production could be increased 2-3 fold through the adoption of improved varieties coupled with recommended production and protection technologies.

In Karnataka, it is grown over an area of 26 thousand ha with a production of 25.27 thousand tonnes and productivity of 972 kg ha^{-1} [2]. In Karnataka, it is mainly grown in Northern districts *viz.,* Raichur, Vijayapura, Kalaburagi, Bidar, Koppal, Yadagiri and Bellary during October to November under conserved soil moisture and limited nutrient conditions with poor management practices. Usually, it is cultivated in rainfed areas. If winter rains fail, it creates soil moisture stress. To overcome this supplemental irrigation is required. In the presence of ambient moisture conditions, higher nutrient solubility, its use and optimized crop uptake leading to good growth of crop and finally improved yields. Hence scheduling of irrigation at different growth stages help to increase the growth and yield by enhanced uptake of nutrients in the presence of soil microorganisms and reducing the impact of soil moistures stress. Efficient water management is important in getting higher yield with good quality produce [5]. Therefore, in the present study the effect of scheduling of irrigation on nutrient uptake and soil microorganisms in linseed was carried out.

MATERIAL AND METHODS

A field experiment was conducted during *rabi* season 2023-24 at Main Agriculture Research Station, Raichur, India, University of Agricultural Sciences, Raichur, Karnataka, India. The soil of the experimental field was sandy loam in texture with alkaline pH (8.39), bulk density (1.61 g cm^{-3}), organic carbon content (0.66 %), available nitrogen (206.58 kg ha^{-1}), phosphorus (23.25 kg ha^{-1}) and potassium (236.98 kg ha^{-1}) contents, at the time of initiation of the experiment. The climate of the area was subtropical, received annual average rainfall of 720 mm and mean maximum and minimum temperature were 38.77^{o}C and 17.76^{o}C, respectively. The experiment was laid out in randomized complete block design with five treatments and replicated four times. There were five treatments *viz*., T_1: Pre sowing irrigation only, T_2: Pre sowing irrigation *fb* one irrigation at vegetative stage (30-35 DAS), T_3: Pre sowing irrigation *fb* two irrigations at vegetative stage (30-35 DAS) and flowering stage (40-45 DAS), T_4: Pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering

stage (40-45 DAS) and capsule development stage (60-65 DAS) and T_5: Rainfed condition. The linseed variety NL-115 having duration of 110-115 days was sown with 30 cm spacing using seed rate of 25 kg ha^{-1}. Fertilizer dose of 40:20:20 kg ha^{-1} in the form of Urea, Diammonium phosphate and Muriate of potash was applied to the soil.

Uptake of nutrients by linseed

The uptake of nutrients by seed and straw of linseed plants was worked out by using the following formula

$$\text{Nutrient uptake by seed (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{dry weight of seed (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient uptake by straw (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{dry weight of straw (kg ha}^{-1}\text{)}}{100}$$

Enumeration of soil microorganisms

After the harvest of the crop, soil samples were collected from different treatments of experimental plots and were used for enumeration of soil microorganisms *viz*., bacteria, fungi and actinomycetes. Each soil sample was sieved through the 1000 micromesh to remove the bigger particles and debris and was used for enumeration of bacteria, fungi and actinomycetes using Nutrient agar, Martin rose bengal agar [11] and Kuster's agar media [10] respectively by serial dilution pour plate method. The plates were incubated for 24-48 hr at 28º C. Colonies that appeared on the media were enumerated and expressed in terms of colonies forming units per gram (cfu g^{-1}) of soil on dry weight basis.

Soil enzymatic activity

The activities of soil enzymes *viz*. dehydrogenase [3], urease [14] and alkaline phosphatase [13] were also measured using suitable methods.

Dehydrogenase activity (µg TPF g^{-1} soil day^{-1})

The dehydrogenase activity in the soil samples was determined by following the procedure as described by Casida *et al*. (1964). Ten grams of soil and 0.2 g $CaCO_3$ were thoroughly mixed and dispensed in the conical flasks. Each flask was added with 1.0 ml of 1.5 per cent, 2, 3, 5-triphenyl tetrazolium chloride (TTC), 1.0 ml of one per cent glucose solution and eight ml of distilled water to leave a thin film of water above soil layer. The flasks were stoppered with rubber bunks and incubated at 30 ^{0}C for 24 hours. At the end of incubation, the contents of the flask were rinsed down into small beaker and slurry was made by adding 10 ml of methanol. The slurry was filtered through Whatman No. 42 filter paper. Repeated rinsing of soil with methanol was continued till the filtrate ran free of red colour. The filtrate was made up to 50 ml with methanol in volumetric flask. The intensity of red colour was measured at 485 ηm against a methanol blank using spectrometer.

The standard curve preparation: Graded concentration of TTC (2, 3, 5-triphenyl tetrazolium chloride) (0.0 - 50.0 µg) were prepared in methanol. In each tube, 5 ml of phosphate buffer (7.4 p^H) and adequate amount (150 mg) of fresh sodium dithionate ($Na_2S_2O_4.H_2O$) were added. When the reduction was complete pink colour intensity of graded concentration of triphenyl formazon (TPF) was red as before. The results were expressed as µg of TPF formed per g of soil per day.

Urease activity (µg NH_4-N g^{-1} soil hr^{-1})

Ten gram of soil samples were treated with 1 ml toluene and 10 ml phosphate buffer and incubated at 30 °C for 2 hr. After incubation, 15 ml IN KCI was added and the contents were filtered through Whatman No. 42. The filtrate volume was made up to 100 ml with distilled water. The 1 ml of the extractant was taken 2 ml of 10% sodium tartarate, 0.5 ml Nessler's reagent were added and incubated for 30 min and volume was made up to 25 ml with distilled water. Colour (yellow) developed was read at 610 ηm against blank (without urease solution) using UV- spectrophotometer. The results were expressed as µg NH_4-N g^{-1} soil $hour^{-1}$.

Alkaline phosphatase activity (µG PNP G^{-1} SOIL HR^{-1})

One gram of soil sample was placed in 50 ml conical flask to which 0.2 ml toluene followed by four ml of modified universal buffer (pH 7.5) was added. One ml of para-nitrophenol phosphate solution made in modified universal buffer was added to the flasks and content of the flasks was mixed by swirling for 2 minutes. The flasks were stoppered and incubated at 37° C for one hour. After incubation, one ml of 0.5 M $CaCl_2$, and four ml of 0.5 M NaOH was added to the flask, swirled and filtered through Whatman No. 42 filter paper. The intensity of yellow colour developed was measured at 420 ηm against the reagent blank using spectrophotometer. Control was maintained for each soil sample and was analyzed by following the same procedure described as above except that the para nitrophenol phosphate solution was added after the addition of 0.5 M $CaCl_2$ and 0.5 M NaOH and just before filtration. The phosphatase activity in the soil samples was expressed as µg para nitrophenol formed per gram soil per hour with reference to the standard curve prepared by using graded concentrations of p-nitrophenol phosphate.

RESULTS AND DISCUSSION

Nitrogen, Phosphorus and Potassium uptake by seed, straw and total uptake (kg ha^{-1})

Nitrogen, Phosphorus and potassium uptake by seed, straw and total uptake differed significantly as influenced by scheduling of irrigation in linseed and presented in Table 1.

Higher nitrogen uptake in seed (27.08 kg ha^{-1}), straw (18.98 kg ha^{-1}) and total nitrogen uptake (46.07 kg ha^{-1}) was recorded with treatment T_4 *i.e.,* pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65

DAS**)**. Significantly lower nitrogen uptake in seed (10.62 kg ha^{-1}), straw (8.73 kg ha^{-1}) and total uptake (19.35 kg ha^{-1}) was recorded with rainfed condition (T_5) which was on par with (T_1) *i.e.,* pre sowing irrigation only (11.52, 9.05 and 20.56 kg ha^{-1} , respectively).

Among different irrigation schedules, T_4 *i.e.,* pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS**)** registered significantly higher phosphorus uptake in seed (9.70 kg ha^{-1}), straw (10.17 kg ha^{-1}) and total uptake (19.87 kg ha^{-1}). Significantly lower phosphorus uptake in seed (3.81 kg ha^{-1}), straw (4.64 kg ha^{-1}) and total uptake (8.15 kg ha^{-1}) was recorded in rainfed condition and was on par with (T_1) *i.e.,* pre sowing irrigation only (4.09, 4.34 and 8.73 kg ha^{-1}, respectively).

Potassium uptake in seed (9.56 kg ha^{-1}), straw (30.27 kg ha^{-1}) and total potassium uptake (39.83 kg ha^{-1}) was significantly higher with pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) (T_4) when compared to all other treatments. Significantly lower uptake of potassium in seed (3.36 kg ha^{-1}), straw (15.04 kg ha^{-1}) and total uptake (18.40 kg ha^{-1}) was noticed in treatment, T_5 (rainfed condition) that was on par with T_1 *i.e.,* pre sowing irrigation only (3.99, 15.89 and 19.88 kg ha^{-1}).

Nutrient uptake is linked to plant metabolic activities as well as the concentration and distribution of ions in the external medium. It has been established that different irrigation schedules had profound impact on the absorption and utilization of major nutrients, which helped in growth and development of plant. At harvest, nitrogen, phosphorus and potassium uptake of linseed differed significantly. Among different treatments, (T_4) pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) recorded significantly higher N, P and K uptake over control in linseed. Higher nutrient uptake might have been aided by the solubility and availability of sufficient quantities of nutrients with optimum soil moisture, combined with improvements in soil characteristics across the entire crop growth cycle. The results in this present investigation are in line with the findings of previous workers [12] and [15].

Table 1: Nitrogen, phosphorus and potassium uptake by linseed at harvest as influenced by scheduling of irrigation

Treatment	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
T_1	11.52	9.05	20.56	4.09	4.64	8.73	3.99	15.89	19.88
T_2	17.45	12.37	29.83	6.20	6.39	12.58	4.97	21.17	26.14
T_3	24.57	17.02	41.60	8.57	9.26	17.83	7.34	27.82	35.15
T_4	27.08	18.98	46.07	9.70	10.17	19.87	9.56	30.27	39.83
T_5	10.62	8.73	19.35	3.81	4.34	8.15	3.36	15.04	18.40
S. Em. ±	**1.06**	**0.95**	**1.66**	**0.49**	**0.36**	**0.61**	**0.30**	**1.51**	**1.67**
C.D. (P = 0.05)	**3.26**	**2.94**	**5.11**	**1.52**	**1.11**	**1.88**	**0.92**	**4.67**	**5.14**

DAS: Days after sowing ***fb*: Followed by**

Soil microorganisms

Among the different treatments, pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) recorded significantly higher soil microbial population of bacteria (16.1 X 10^6 cfu g^{-1} of soil), fungi (13.8 X 10^4 cfu g^{-1} of soil) and actinomycetes (6.8 X 10^3 cfu g^{-1} of soil) as compared to other treatments. Whereas, significantly lower soil microbial population of bacteria (13.4 X 10^6 cfu g^{-1} of soil), fungi (10.3 X 10^4 cfu g^{-1} of soil) and actinomycetes (4.1 X 10^3 cfu g^{-1} of soil) was recorded with rainfed condition (Table 2).

The soil enzyme activity was significantly influenced by scheduling of irrigation at different growth stages in linseed. At harvest among the different treatments, pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) recorded significantly higher dehydrogenase, urease and alkaline phosphatase activity (18.63 µg TPF g^{-1} soil day^{-1}, 22.5 µg NH_4-N g^{-1} soil hr^{-1} and 14.4 µg PNP g^{-1} soil hr^{-1}, respectively). However, it was on par with pre sowing irrigation *fb* two irrigations at vegetative stage (30-35 DAS) and flowering stage (40-45 DAS) (17.7 µg TPF g^{-1} soil day^{-1}, 21.8 µg NH_4-N g^{-1} soil hr^{-1} and 13.6 µg PNP g^{-1} soil hr^{-1}, respectively) (Table 3).

Soil microbial biomass, the active fraction of soil serves as an index of soil fertility. Before irrigation, population of microorganisms did not differ significantly among the treatments. Whereas, bacterial, fungal and actinomycetes population increased from initial stage to flowering stage, when the crop was fully established. It may be concluded that, pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS) positively impacted the soil microbial population. The lowest values of these colonies were observed in rainfed condition. The lower microbial load might be due to moisture deficiency which caused stress and death of microbes in soil. Similar results were also reported by many workers [6], [7], [8] and [9].

Table 2: Soil microbial population as influenced by scheduling of irrigation in linseed

Treatment	Bacteria (cfu x 10^6 g^{-1} soil)		Fungi (cfu x 10^4 g^{-1} soil)		Actinomycetes (cfu x 10^3 g^{-1} soil)	
	Initial	At harvest	Initial	At harvest	Initial	At harvest
T_1: Pre sowing irrigation only	13.9	14.1	10.1	11.2	4.7	4.9
T_2: Pre sowing irrigation *fb* one irrigation at vegetative stage (30-35 DAS)	14.7	14.8	10.4	12.3	4.9	5.4
T_3: Pre sowing irrigation *fb* two irrigations at vegetative stage (30-35 DAS) and flowering stage (40-45 DAS)	14.3	15.2	11.1	13.5	5.6	6.3
T_4: Pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule	14.6	16.1	11.3	13.8	5.9	6.8

development stage (60-65 DAS)

T_5: Rainfed condition	13.3	13.4	9.6	10.3	4.3	4.1
S. Em. ±	**0.3**	**0.4**	**0.4**	**0.3**	**0.4**	**0.2**
C.D. at 5%	**NS**	**1.2**	**NS**	**1.0**	**NS**	**0.8**

DAS: Days after sowing ***fb*: Followed by** **NS: Non significant**

Table 3: Soil enzyme activity as influenced by scheduling of irrigation in linseed

Treatment	Dehydrogenase (µg TPF g^{-1} soil day^{-1})		Urease (µg NH_4-N g^{-1} soil hr^{-1})		Alkaline phosphatase (µg PNP g^{-1} soil hr^{-1})	
	Initial	At harvest	Initial	At harvest	Initial	At harvest
T_1: Pre sowing irrigation only	5.9	13.0	15.8	19.3	7.9	11.5
T_2: Pre sowing irrigation *fb* one irrigation at vegetative stage (30-35 DAS)	6.5	14.4	15.9	20.4	8.1	12.9
T_3: Pre sowing irrigation *fb* two irrigations at vegetative stage (30-35 DAS) and flowering stage (40-45 DAS)	6.8	17.7	16.2	21.8	8.3	13.6
T_4: Pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS)	6.9	18.6	16.5	22.5	8.4	14.4
T_5: Rainfed condition	5.7	12.0	15.6	18.1	7.9	10.3
S. Em. ±	**0.3**	**0.7**	**0.3**	**0.3**	**0.4**	**0.4**
C.D. at 5%	**NS**	**2.0**	**NS**	**0.9**	**NS**	**1.6**

DAS: Days after sowing ***fb*: Followed by**

TPF: Tri phenyl formazan **PNP: Para nitrophenol**

CONCLUSION

From the above discussion it can be concluded that, increasing trend of nutrient uptake with increase in amount of water utilised and in rainfed condition significantly lower nutrient uptake was seen. Whereas, pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS), significantly higher nutrient uptake was observed. Higher microbial population was observed with pre sowing irrigation *fb* three irrigations at vegetative stage (30-35 DAS), flowering stage (40-45 DAS) and capsule development stage (60-65 DAS). Further in the same treatment significantly higher dehydrogenase, urease and alkaline phosphatase activity was seen. Whereas, rainfed condition recorded significantly lower soil microbial population and enzyme activity was found.

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