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Water use efficiency of Linseed (*Linum usitatissimum*) as influenced by tillage practices and irrigation schedule grown after Rice of Chhattisgarh plain

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Abstract

Linseed *(Linum usitatissimum* (L.) Griesb.) also known as flaxseed, is one of the most versatile and useful crop grown either for oil from seed or for fibre from stem. Linseed yields seed which is a rich source of both non-edible and edible oil. Ph.D research on "Agro-resource management studies on growth, yield, quality and economics of linseed (*Linum usitatissimum* Linn.) grown after rice in Alfisols of Chhattisgarh plains" was conducted during *rabi* seasons of 2009-10 and 2010-11 at Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur with the specific objectives to study the effect of different tillage with varying levels of irrigation on growth, yield, nutrient uptake and economics of linseed. Two different experiments on linseed crop were undertaken during two consecutive *rabi seasons of* 2009-10 & 2010-11. The experiment was divided into horizontal and vertical plots under strip plot design. The horizontal plot was further divided into four tillage practices *viz.* zero tillage (T_0), harrowing once (T_1), rotavator once (T_2) and conventional tillage (T_3) and vertical plots were divided into four irrigation schedules *viz.* one irrigation after seeding (I_0), one irrigation at 35 DAS (I_1), two irrigations at 35 and 75 DAS (I_2) and three irrigations at 0, 35 and 75 DAS (I_3).

Keywords: Linseed, water, management

Introduction

Its seed is small, flat, oval, brown, fawn or yellow coloured, glossy in appearance with oily mucilaginous taste and constituted 30-45% of fixed oil. Seed is very rich source of nutrients *viz.*, moisture (6.5%), protein (20.3%), fat (37.1%), minerals (2.4%), carbohydrates (28.9%), energy (530 K. Cal.), calcium (170 mg/100 g), iron (370 mg/100 g), carotenes (2.7 micro g / 100 g), thiamine (0.23 mg/100 g), riboflavin (0.07 mg / 100 g) and niacin (1.0 mg/100 g) (Gopalan *et al.*, 1987) [5].

Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.*, 2006) [8]. Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel, 1989) [6]. The proper use of tillage can improve soil related constrains, while, improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility and disruption in cycles of water, organic carbon and plant nutrient. Use of excessive and un-necessary tillage operations is often harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal *et al.*, 2005) [7].

Water is vital for the survival of plant. Cell division and its elongation depend on water absorption. Lack of water causes stomata to close, consequently rate of photosynthesis is reduced, resulting in poor plant growth and yield. Scientific water management aims to provide suitable moisture, condition for the crop to obtain optimum yields, commensurate with maximum economy in irrigation water and maintenance of soil productivity. The water management technology is highly location specific and as such the management decisions vary with the quantity, quality and time of water availability, topography, soil texture and depth, climatic conditions, crops to be grown, sowing time and other agronomic practices etc.

Keeping above facts in view and considering the benefits and increased popularity of linseed, Ph.D., research entitled "Agro-resource management studies on growth, yield, quality and economics of linseed (*Linum usitatissimum* Linn.) grown after rice in Alfisols of Chhattisgarh plains" was conducted during *rabi* seasons of 2009-10 and 2010-11 at Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur with the following specific objectives: to study the effect of different tillage with varying levels of irrigation on growth, yield, nutrient uptake and economics of linseed.

Materials and Methods

Location and Experimental Site

The location of the experimental site was Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) located at 21°4' N latitude and 81°39' E longitude with an altitude of 298 metre above mean sea level having sub tropical humid climate.

Climate Conditions

The climate of Raipur region is sub humid with hot and dry summer and mild winter. It comes under the Chhattisgarh plains agro- climatic sub zone of seventh agro climatic region of India i.e. eastern plateau and hills. The average annual rainfall is about 1320 mm of which about 88% is received during a span of four months i.e. between June to September. The rainfall is largely contributed by south-west monsoon. The maximum temperature raises up to 45 °C during summer and minimum temperature falls to 5-6 °C during winter season. The relative humidity reaches maximum 93% and minimum 41% in August and March, respectively.

Treatment Details

Two different experiments on linseed crop were undertaken during two consecutive *rabi seasons of* 2009-10 & 2010-11. The experiment was divided into horizontal and vertical plots under strip plot design. The horizontal plot was further divided into four tillage practices *viz*. zero tillage (T_0), harrowing once (T_1), rotavator once (T_2) and conventional tillage (T_3) and vertical plots were divided into four irrigation schedules *viz*. one irrigation after seeding (I_0), one irrigation at 35 DAS (I_1), two irrigations at 35 and 75 DAS (I_2) and three irrigations at 0, 35 and 75 DAS (I_3). The experiment was sown on 26th November, 2010 and harvested on 24th March, 2011.

Water management

Effective rainfall (mm)

Effective rainfall was considered from amount of water evaporated and rainfall received. The days when crop received rainfall less than evaporation was considered as effective rainfall (ER). In flood irrigation treatment, after every ten days irrigation was applied by measuring the discharge rate of pump, so that all the received rainfall was considered as ER if it is below the sum of ten days evaporation.

Total water use (mm)

Total water use was calculated and derived from crop factor and pan factor according to imposed treatments. The amount of water evaporated from crop land was applied through drip and flood method, except the day's crop received rain more than evaporation and sum of applied water during crop growth period was considered as water requirement.

Water use efficiency (WUE)

WUE (kg ha^{-1} mm^{-1}) was calculated as the ratio of maize yield to water requirement (mm) of linseed crop.

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Linseed yield (kg ha}^{-1})}{\text{Water requirement (mm)}}$$

Result and Discussion

Seed yield (q ha^{-1})

The seed yield of linseed as influenced by tillage practices and irrigation schedules are presented in Table 1. The seed yield of linseed was prominently influenced by tillage practices and irrigation schedules. Linseed crop grew with conventional tillage (T_3) resulted in highest seed yield of 10.58, 10.47 and 10.52 q ha^{-1} during 2009-10, 2010-11 and on mean basis, respectively, being significantly superior compared to respective seed yield of 7.42, 7.18 and 7.30 q ha^{-1} under zero tillage (T_0). However, it was at par to treatment harrowing once (T_1) and rotavator once (T_2) during both the years and on mean basis.

As regards to different irrigation schedules, linseed crop grew with three irrigation *viz.*, at sowing, 35 and 75 DAS (I_3) produced significantly higher seed yield compared to one irrigation after seeding (I_0) and one irrigation at 35 DAS (I_1), but it was at par to two irrigations at 35 and 75 DAS (I_2) during both the years and on mean basis.

Among the different tillage practices, maximum mean seed yield was obtained for treatment conventional tillage (10.52 q ha^{-1}) followed in decreasing order by rotavator once (9.27 q ha^{-1}), harrowing once (9.09 q ha^{-1}) and zero tillage (7.30 q ha^{-1}). The maximum yield in conventional tillage may be due to better pulverisation of soil resulting in proper seed and soil contact, which caused good germination (plants m^{-2}). The lowest yield was observed in treatment zero tillage because of poor seed and soil contact, as the clod size was big and did not create good tilth for proper germination of crop (plants m^{-2}). This increase in seed yield was due to significant increase in growth parameters and yield attributes such as seeds capsule^{-1}, and capsules plant^{-1}.

Seed yield increased significantly with the increase of irrigation schedule. Maximum mean seed yield (11.45 q ha^{-1}) was obtained under irrigation schedule three irrigations at 0, 35 and 75 DAS (I_3) which was 9.43 and 30.65 per cent higher than two irrigations at 35 and 75 DAS (I_2) and one irrigation at 35 DAS (I_1), respectively. This increase in seed yield was due to significant increase in growth parameters and yield attributes like seeds capsule^{-1}, capsules plant^{-1} and test weight. The increase in grain yield and yield attributes with the higher level of irrigation were also reported by Gautam *et al.* (2000) [4] and Mishra *et al.* (2002) [9]. Significantly higher growth parameters due to high irrigation levels were also reported by Roy and Tripathi (1987) [12], Prasad and Prasad (1989) [11], Bandopadhyay and Mallick (1996) [1], Banga *et al.* (1998) [3] and Bandopadhyay and Mallick (2000) [2].

Stalk yield (q ha^{-1})

The stalk yield of linseed as influenced by tillage practices and irrigation schedule are presented in Table 1. The stalk yield varied significantly due to tillage practices and irrigation schedules during both the years and on mean basis. A perusal of the data indicates that crop planted under conventional tillage (T_3) has been given significantly higher stalk yield than zero tillage (T_0), but it was at par to harrowing once (T_1) and rotavator once (T_2) during both the years and on mean basis.

It is clear from the result that different irrigation schedules influenced the stalk yield of linseed. Linseed crop provided with three irrigations *viz*., at sowing, 35 and 75 DAS (I_3) resulted in significantly higher stalk yield, being significantly superior over one irrigation after seeding (I_0) and one irrigation at 35 DAS (I_1) but remained at par to two irrigations at 35 and 75 DAS (I_2) during both the years and on mean basis. Increasing tillage also resulted in significant increase in the stalk yield. Significantly maximum stalk yield was recorded under conventional tillage (T_3) and it was 7.38 and 6.78% higher over harrowing once (T_1) and rotavator once (T_2), respectively. This increase in stalk yield could be due to the increase in LAI, dry matter accumulation and plant height. Indirectly, it may also have contributed for higher yield because higher stalk yield.

Significantly maximum stalk yield was recorded under three irrigations at 0, 35 and 75 DAS (I_3) and it was 5.49 and 13.96% higher over two irrigations at 35 and 75 DAS (I_2) and one irrigation at 35 DAS (I_1), respectively. Adequate available soil moisture in the root zone depth of soil due to frequent irrigation might have improved the nutrient availability, thereby increasing cell division and cell expansion which in turn increased the total dry matter production at three irrigation. Panchanathan *et al.* (1992) observed that when the crop was supplied with adequate moisture throughout the growing period and reduction was noticed with imposition of moisture stress. This indicate that moisture supply has a direct bearing on the production of ultimate stalk yield.

Table 1: Seed yield, stalk yield and biological yield of linseed as influenced by tillage practices and irrigation schedule

Treatment	Seed yield (q ha^{-1})			Stalk yield (q ha^{-1})			Biological yield (q ha^{-1})		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
Tillage practices									
T_0 : Zero tillage	7.42	7.18	7.30	18.55	17.89	18.22	25.97	25.08	25.52
T_1 : Harrowing once	9.13	9.05	9.09	21.55	21.32	21.43	30.68	30.37	30.52
T_2 : Rotavator once	9.29	9.26	9.27	21.75	21.39	21.57	31.04	30.65	30.84
T_3 : Conventional tillage	10.58	10.47	10.52	23.38	22.91	23.14	33.95	33.38	33.66
SEm±	0.60	0.63	0.63	0.54	0.59	0.49	0.97	1.15	0.95
CD (P=0.05)	2.08	2.20	2.18	1.88	2.07	1.71	3.38	4.00	3.30
Irrigation schedule									
I_0 : One (After seeding)	6.46	6.38	6.42	17.53	17.39	17.46	23.98	23.78	23.88
I_1 : One (35 DAS)	7.97	7.92	7.94	20.97	20.08	20.52	28.93	27.99	28.46
I_2 : 35 and 75 DAS	10.46	10.29	10.37	22.77	22.32	22.54	33.23	32.61	32.92
I_3 : 0, 35 and 75 DAS	11.53	11.37	11.45	23.97	23.73	23.85	35.50	35.09	35.29
SEm±	0.35	0.57	0.32	0.64	0.80	0.59	0.73	0.80	0.65
CD (P=0.05)	1.21	1.97	1.19	2.23	2.77	2.05	2.53	2.79	2.25

Table 2: Irrigation and water requirement and water use efficiency as influenced by tillage practices and irrigation schedule

Treatment	Irrigation water applied (mm)			Effective rainfall (mm)			Total water used (mm)			Water use efficiency (kg ha^{-1} mm^{-1})		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
Tillage Practices												
T_0 : Zero tillage	105	105	105	43.8	12.6	28.2	148.8	117.6	133.2	2.77	2.66	2.71
T_1 : Harrowing once	105	105	105	43.8	12.6	28.2	148.8	117.6	133.2	3.46	3.43	3.44
T_2 : Rotavator once	105	105	105	43.8	12.6	28.2	148.8	117.6	133.2	3.51	3.51	3.51
T_3 : Conventional tillage	105	105	105	43.8	12.6	28.2	148.8	117.6	133.2	4.02	3.98	4.00
SEm±										0.27	0.32	0.30
CD (P=0.05)										0.96	1.12	1.04
Irrigation schedule												
I_0 : One (After seeding)	60	60	60	43.8	12.6	28.2	103.8	72.6	88.2	2.96	2.92	2.94
I_1 : One (35 DAS)	60	60	60	43.8	12.6	28.2	103.8	72.6	88.2	3.65	3.62	3.64
I_2 : 35 and 75 DAS	120	120	120	43.8	12.6	28.2	163.8	132.6	148.2	3.95	3.89	3.92
I_3 : 0, 35 and 75 DAS	180	180	180	43.8	12.6	28.2	223.8	192.6	208.2	3.40	3.35	3.37
SEm±										0.25	0.25	0.26
CD (P=0.05)										0.81	0.80	0.83

Biological yield (q ha^{-1})

The biological yield of linseed as influenced by tillage practices and irrigation schedules are presented in Table 1. It is evident from the results that biological yield was greatly affected by tillage practices and irrigation schedules. Crop planted with conventional tillage (T_3) recorded significantly higher biological yield than that produced by zero tillage (T_0) but, it was at par with harrowing once (T_1) and rotavator once (T_2) during both the years and on mean basis.

Among the different irrigation schedules, crop irrigated at sowing, 35 and 75 DAS (I_3) produced significantly higher biological yield than one irrigation after seeding (I_0) and one irrigation at 35 DAS (I_1) but, it was at par to two irrigations at 35 and 75 DAS (I_2) during both the years and on mean basis.

Water Use Efficiency (WUE)

The total water used and water use efficiency (WUE) were calculated treatment wise and year wise and data are presented in Table 2. As regards to different tillage practices, significantly higher water use efficiency was recorded under conventional tillage (T_3) over zero tillage (T_0) but it was at par with harrowing once (T_1) and rotavator once (T_2) during both the years and on mean basis.

Among the irrigation schedules, significantly higher water use efficiency was noted with two irrigations scheduled at 35 and 75 DAS (I_2) over one irrigation after seeding (I_0) but it was at par to three irrigations at 0, 35 and 75 DAS (I_3) and one irrigation at 35 DAS (I_1) during both the years and on mean basis.

The total water use efficiency was influenced due to different tillage practices and rrigation schedules. Highest water use efficiency was observed under conventional tillage (T_3) followed by harrowing once (T_1) and rotavator once (T_2) and zero tillage (T_0) in decreasing order. The highest total water use efficiency in conventional tillage (T_3) might be due to the low plant canopy and increased direct soil evaporation as well as higher vapour pressure gradient between canopy air and atmospheric air was probably responsible for greater water use. Similar results under soybean were also reported by Tedia (1988). While, lower total water use and water use efficiency was observed under zero tillage (T_0) which might be attributed to low rooting depth and density, in the soil water potential to which root can extract water, in canopy development and in stomatal control of water loss.

The total irrigation and water requirement increased with irrigation level and obviously high in three irrigations at 0, 35 and 75 DAS (I_3) due to more frequency of irrigation than rest of the treatment. On the contrary, the maximum water use efficiency was noted in two irrigations at 35 and 75 DAS (I_2) followed by one irrigation at 35 DAS (I_1) and three irrigations *viz*., at sowing, 35 and 75 DAS (I_3). It is due to wide ratio of water used and yield received under these treatments. The similar results were observed by (Singh and Rao, 1994) [13] for coriander and (Yadav and Dhama, 2003) [15] for cumin.

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