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Impact on Bulk density, infiltration rate and organic carbon as influenced by tillage practices and irrigation schedule of Linseed (*Linum usitatissimum*) 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, bulk density, management

Introduction
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) [10]. Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel, 1989) [7]. 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) [8]. Conservational tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact (Rashidi and Keshavarzpour, 2007) [19].
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.

Bulk density (Mg m^{-3})

The core sampler method (Black and Hartge, 1986) was used to determining the bulk density cores of 0.06 m diameter and 0.07 m height were used for taking the undisturbed soil core from 0-0.07 m and 0.15-0.22 m depth. The soil samples were drawn at initial stage and at harvest of linseed during both the years. These sample cores drawn from the soil were oven dried at 105^{0}C for 48 hours and bulk density was calculated by using the following formula

$$\text{BD (Mg m}^{-3}) = \frac{\text{Oven dry weight of soil (Mg)}}{\text{Volume of soil (m}^3)}$$

Infiltration rate (cm hr^{-1})

Infiltration rate was measured *in-situ* as per the method described by Bouwer (1986). Measurement of infiltration was made at harvest of linseed crop by using a double ring infiltrometer. The two concentric rings of 0.30 and 0.50 m diameter and 0.30 m height were used. The rings were driven to a depth of 0.10 m into soil by hammering gently by wooden piece placed on the top of rings. The fall in water level in the inner ring at different time intervals was measured with the help of hook guage at 20, 40 and 60 minute till the constant reading was obtained. Water head of 0.10 m was maintained in both the rings during measurement.

Organic carbon

Soil samples were collected from each plot following the standard soil sampling at initially and after harvest of linseed crops. Analysis of organic carbon (Walkley and Blacks rapid titration method: Black, 1965), available N (Alkaline permanganate method: Subbiah and Asija, 1956), P (Olsens NAHCO3; Olsen, 1954) and K (Flame photometer method: Jackson, 1973) were carried out.

Result and discussion

Soil analysis

Bulk density (Mg m^{-3})

The data on bulk density of soil at harvest are given in Table 1. The bulk density at harvest was significantly influenced by different tillage practices and irrigation schedules. Among tillage practices, significantly higher bulk density was observed under zero tillage (T_0) as compared to conventional tillage (T3), but it was at par to harrowing once (T_1) during both the years and on mean basis as well as rotavator once (T_2) during 2009-10 and on mean basis. As regards to irrigation schedules, the bulk density of soil at harvest remained unaffected.

The bulk density in conventional tillage (T_3) was significantly lower as compared to zero tillage (T_0), harrowing once (T_1) and rotavator once (T_2) during both the years. The decrease in bulk density under tilled plots may be due to increase in non-capillary porosity and low soil mass per unit volume. Owing to the progressive increase in bulk density after tillage, the difference between the tilled and no tilled treatments become smaller and smaller with the time since tillage progresses. This increase was the result of natural reconsolation of soil particles become of subsequent irrigation and summer drying. The results are in line with the finding of Jat *et al.* (2006) [9]. The higher bulk density under zero or reduced tillage might be due to more porus with increased intensity of tillage in conventional practices. The result confirm are the finding of Dhiman *et al*. (1998) [5]. The volume of soil was increased due to pulverization which ultimately resulted in lower value of bulk density under conventional tillage. Mehta *et al*. (1996) [13] and Kumar (2000) [11] also found that comparison to reduced or zero tillage system.

Infiltration rate (cm hr^{-1})

The data on the effect of different tillage practices and irrigation schedules on infiltration rate are presented in Table 1. Results revealed that under tillage practices significantly higher infiltration rate was recorded with conventional tillage (T_3) over zero tillage (T0) but, it was at par with harrowing once (T_1) and rotavator once (T_2). Among the irrigation schedules, maximum rate of infiltration was recorded under three irrigations provided at sowing, 35 and 75 DAS (I_3) followed by two irrigations at 35 and 75 DAS (I_2) and one irrigation at 35 DAS (I_1). One irrigation after seeding (I_0) registered lowest infiltration rate during both the years and on mean basis.

Tillage for linseed cultivation opened the soil and increased the infiltration rate as compared with relatively undisturbed soil in zero tillage system. The final infiltration rate was higher in conventional tillage, harrowing once and rotavator once tillage system might be due to high porosity causing saturated flow down to the soil profile. These results are conformity with the result reported by Lal and Van doren (1990) [12] and also Chitale (2006) [4]. They further reported that initial infiltration rate was higher in zero tillage as compared to other tillage practices treatment. Among irrigation management, the higher infiltration rate was noted with three irrigations at 0, 35, 75 DAS (I_3) followed by two irrigations at 35 and 75 DAS (I_2) and one irrigation at 35 DAS (T_1).

Organic carbon (%)

The data on organic carbon content in soil at harvest are given in Table 1. The organic carbon content was significantly influenced by different tillage practices. Significantly higher organic carbon content was exhibited under zero tillage (T_0) than conventional tillage (T_3) but, it was at par to harrowing once (T_1) and rotavator once (T_2) during both the years and on mean basis. Irrigation schedule could not bring any significant variation in organic carbon content during both the years and on mean basis.

The data pertaining to organic carbon content showed that it was significantly highest under zero tillage (T_0) as compared to other tillage practices. This might be due to the entire crop residue was left such as the surface as well as decay of roots. This could be the reason for higher organic carbon content. These results were in agreement with Pratibha *et al*. (1995) [18].

Seed yield (q ha^{-1})

The seed yield of linseed as influenced by tillage practices and irrigation schedules are presented in Table 2. 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) [6] and Mishra *et al.* (2002) [14]. Significantly higher growth parameters due to high irrigation levels were also reported by Roy and Tripathi (1987) [17], Prasad and Prasad (1989) [16], 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 2. 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) [15] 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.

Biological yield (q ha^{-1})

The biological yield of linseed as influenced by tillage practices and irrigation schedules are presented in Table 2. 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.

Harvest index (%)

The data on harvest index as influenced by tillage practices and irrigation schedules have been summarized in Table 2. A perusal of the data shows that there was significant influence of tillage practices and irrigation schedules on harvest index of linseed during both the years and on mean basis. Crop sown with conventional tillage (T_3) registered significantly higher harvest index over zero tillage (T_0) but, it was statistically similar to harrowing once (T_1) and rotavator once (T_2) during both the years and on mean basis.

As regards to effect of different irrigation schedules, three irrigations at sowing, 35 and 75 DAS (I_3) has resulted in significantly higher harvest index 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.

Harvest index of linseed differed significantly due to interaction effects of tillage practices and irrigation schedules during both the years and on mean basis (Table 4.18). At the same or different level of tillage the significantly higher harvest index was obtained with interaction between conventional tillage (T_3) x three irrigations at 0, 35 and 75 DAS (I_3) as compared to other interactions but, it was at par to interaction between conventional tillage x two irrigations at 35 and 75 DAS (T_3 x I_2), rotavator once x two irrigations at 35 and 75 DAS (T_2x I_2), rotavator once x three irrigations at 0, 35 and 75 DAS (T_2 x I_3), harrowing once x two irrigations at 35 and 75 DAS (T_1 x I_2), harrowing once x three irrigations at 0, 35 and 75 DAS (T_1 x I_3) , zero tillage x two irrigations at 35 and 75 DAS (T_0 x I_2), and zero tillage x three irrigations at 0, 35 and 75 DAS (T_0 x I_3) during both the years and on the mean basis.

This might be due to more availability of nutrients, moisture, light and space to linseed plants. The better growth and development of linseed crop was due to availability of nutrients in balanced form in sufficient quantity. The allocation of proper space to individual plants provide congenial environment for proper utilization of nutrient, moisture and solar radiation resulted better photosynthesis which in turn produced higher value of yield attributes and seed yield throughout the growing period. Chitale *et al.* (2007) also reported the similar results.

Table 1: Bulk density, infiltration rate and organic carbon in soil of linseed at harvest as influenced by tillage practices and irrigation schedule

Treatment	Bulk density (Mg m^{-3})			Infiltration rate (cm hr^{-1})			Organic carbon (%)		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
Tillage practices									
T_0 : Zero tillage	1.52	1.54	1.53	2.33	2.27	2.30	0.64	0.63	0.63
T_1 : Harrowing once	1.45	1.47	1.46	2.72	2.70	2.71	0.55	0.54	0.54
T_2 : Rotavator once	1.44	1.45	1.44	2.72	2.69	2.70	0.56	0.54	0.55
T_3 : Conventional tillage	1.43	1.44	1.43	2.82	2.73	2.77	0.54	0.52	0.53
SEm±	0.02	0.02	0.03	0.05	0.04	0.04	0.03	0.03	0.03
CD (P=0.05)	0.08	0.08	0.09	0.20	0.17	0.18	0.09	0.10	0.09
Irrigation schedule									
I_0 : One (After seeding)	1.42	1.42	1.42	2.21	2.17	2.19	0.52	0.51	0.51
I_1 : One (35 DAS)	1.45	1.46	1.45	2.47	2.40	2.43	0.53	0.53	0.53
I_2 : 35 and 75 DAS	1.46	1.48	1.47	2.65	2.57	2.61	0.56	0.54	0.55
I_3 : 0, 35 and 75 DAS	1.49	1.50	1.49	2.73	2.70	2.71	0.59	0.57	0.58
SEm±	0.02	0.03	0.03	0.04	0.03	0.04	0.04	0.03	0.04
CD (P=0.05)	NS	NS	NS	0.18	0.11	0.17	NS	NS	NS

Table 2: Seed yield, stalk yield, biological yield and harvest index 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})			Harvest index (%)		
	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	7.42	7.18	7.30	18.55	17.89	18.22	25.97	25.08	25.52	27.28	27.33	27.30
T_1 : Harrowing once	9.13	9.05	9.09	21.55	21.32	21.43	30.68	30.37	30.52	29.43	29.60	29.51
T_2 : Rotavator once	9.29	9.26	9.27	21.75	21.39	21.57	31.04	30.65	30.84	29.60	29.88	29.74
T_3 : Conventional tillage	10.58	10.47	10.52	23.38	22.91	23.14	33.95	33.38	33.66	31.16	31.37	31.26
SEm±	0.60	0.63	0.63	0.54	0.59	0.49	0.97	1.15	0.95	1.01	0.40	0.45
CD (P=0.05)	2.08	2.20	2.18	1.88	2.07	1.71	3.38	4.00	3.30	3.50	1.81	1.57
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	26.16	26.10	26.13
I_1 : One (35 DAS)	7.97	7.92	7.94	20.97	20.08	20.52	28.93	27.99	28.46	27.25	27.91	27.58
I_2 : 35 and 75 DAS	10.46	10.29	10.37	22.77	22.32	22.54	33.23	32.61	32.92	31.58	31.79	31.68
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	32.47	32.38	32.42
SEm±	0.35	0.57	0.32	0.64	0.80	0.59	0.73	0.80	0.65	0.81	1.17	0.77
CD (P=0.05)	1.21	1.97	1.19	2.23	2.77	2.05	2.53	2.79	2.25	2.82	3.88	2.69

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