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ORIGINAL ARTICLE **OPEN ACCESS**

Response of root development and quality parameters on linseed (*Linum Usitatissimum* L.) based intercropping systems as influenced by integrated nutrient management under rainfed condition

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ABSTRACT
A field experiment was conducted during rabi seasons of 2015-16 and 2016-17 at Soil Conservation and Water Management Farm of C S Azad University of Agriculture and Technology, Kanpur to find out suitable row ratio of linseed + lentil/barley in intercropping systems under rainfed condition. The results clearly revealed that root depth (cm), number of root plant^{-1} and dry weight of roots plant^{-1} (g) of linseed, lentil and barley was influenced significantly in sole cropping as compared to intercropped treatments. Amongst the cropping system the maximum root depth (cm), number of root plant^{-1} and dry weight of roots plant^{-1} (g) was obtained in linseed + lentil (3:1) and linseed + barley (3:1) during the two different years. The use of integrated nutrient management further exhibited the significance over RDN. Linseed oil yield was highest (378.30 & 345.80 kg ha^{-1}) in the treatment of linseed + lentil (3:1) during 2015-16 & 2016-17, respectively. The application of INM further showed significance and use of 75% RDN through inorganic + 25% RDN through vermicompost + bio-fertilizer (seed coating) + PSB @ 2.5 kg ha^{-1} in soil exhibited significantly higher values during the years of study. Maximum oil in linseed & protein in lentil & barley was found in relevant sole crops of linseed, lentil and barley whereas highest oil of 38.92 & 38.00 per cent in linseed and protein of 26.10 & 25.65 per cent in lentil was observed in the treatment of linseed + lentil (3:1), protein of 13.13 & 13.03 per cent in barley was observed in the treatment of linseed + barley (3:1) during the two different years.
Key words: *Rainfed, Integrated nutrient management, Equivalent yield, Land equivalent ratio, Vermicompost.*

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INTRODUCTION

Water is most important natural resources, which is scarce at certain times and certain places. India ranks first among the countries that practice rainfed agriculture [11]. Rainwater is essential source of water for agriculture, human beings and animals [6].The primary source of water supply for agriculture in most parts of the world is rainfall. The characteristics of rainfall vary from place to place, day to day, month to month and also year to year [7]. Livelihood security with a strong commitment for natural resource conservation would be the foremost challenge of the 21st century. Globally, 80 per cent area of agriculture is rainfed and contributes 60 per cent the world's food basket. Current productivity of rainfed agriculture is low i.e. less than 1 t ha^{-1} and needs to be increased for sustainable agricultural productivity to achieve second green revolution. Holistic development of the rainfed areas is one of the prime concerns of the Government of India. About 60 per cent of the total arable land of 142 m ha in the country are rainfed which are characterized by low productivity, [5], low income, low employment with high incidence of poverty. Oilseeds, cereals and pulses are the important field crops providing vegetable fat, carbohydrate and proteins of human consumption. In India, oilseeds are grown on about 25.7 m ha area with 26.7 metric tonnes production and productivity of 1037 kg ha[1]. Moreover, India is an important linseed growing country 14 per cent in the world linseed pool. The major linseed producing states are Madhya Pradesh, Chhattisgarh, Maharashtra, Uttar Pradesh, Bihar, Orissa, Jharkhand, Nagaland,

Karnataka and Assam which together account for >95 per cent of the total area. Linseed (*Linum usitatissimum* L.) is important oilseed crop grown for both seed and fiber in south-west Asia including Afganistan, in India, it is primarily grown for oil. It is an industrial oil and mostly 80 per cent of oil is used for paints, varnishes a wide range of coating oil, linoleum, pad and printing inks, leather and soap industries [1].

MATERIAL AND METHODS

A field experiment was conducted during *rabi* seasons of 2015-16 and 2016-17 at Soil Conservation and Water Management Farm of C S Azad University of Agriculture and Technology, Kanpur in alluvial soil under rainfed condition. The Soil of the experimental field was sandy loam in texture and slightly calcareous having organic carbon 0.32%, total nitrogen 0.03%, available P_2O_5 16.0 kg ha^{-1}, available K_2O 155 kg ha^{-1}, pH 7.7, electrical conductivity 0.37 dS m^{-1}, permanent wilting point 6.2%, field capacity 18.4%, maximum water holding capacity 29.6%, Bulk density 1.46 Mg m^{-1}, Particle density 2.56 Mg m^{-1} and porosity 42.9%. The field experiment was conducted in a split-plot design with three replications, keeping cropping systems in main plots and INM in sub-plots. The treatments comprised 9 cropping systems *viz.* **C_1 :** Linseed sole, **C_2 :** Lentil sole, **C_3 :** Barley sole, **C_4 :** Linseed + lentil (3:1), **C_5 :** Linseed + barley (3:1), **C_6 :** Linseed + lentil (4:1), **C_7 :** Linseed + barley (4:1), **C_8 :** Linseed + lentil (5:1) and **C_9 :** Linseed + barley (5:1) and 3 integrated nutrient management *viz.* **N_1 :** RDN, **N_2 :** 75% RDN through inorganic + 25% RDN through vermicompost **N_3 :** 75% RDN through inorganic + 25% RDN through vermicompost + bio-fertilizer (seed coating) + PSB @ 2.5 kg ha^{-1} in soil. Linseed cv Padmini, lentil cv K-75 and barley cv Haritma was grown 25 cm apart. Crops were sown on 20.11.2015 and 26.11.2016 where as linseed was harvested on 30.03.2016 and 03.04.2017, lentil 04.04.2016 and 06.04.2017 and barley on 26.03.2016 and 01.04.2017 during the first and second year of experimentation, respectively. Available moisture at sowing time up to 100 cm soil profile was measured which was 281.7 and 277.5 mm whereas the amount of rainfall received during cropping season was 49.9 and 32.8 mm in 2015-16 and 2016-17, respectively against the average annual rainfall of about 800 mm. Recommended package of practices and fertilizers doses were applied in different treatments. Root study was done at harvest by selecting three plants from each treatment randomly. The roots were subjected to wash with a jet of water spray so that the fine rootlets are not broken. Observations were made on depth of root penetration, number of root $plants^{-1}$ and dry weight of root $plants^{-1}$.The oil content of the oven dried seeds was estimated by extracting oil using petroleum ether (60-80^{0}C) as solvent and Soxhlet apparatus as given by [10]. The oil yield (Kg ha^{-1}) was calculated using following formula:

Oil yield (Kg ha^{-1}) = Seed oil content (%) x Seed yield (Kg ha^{-1})

Protein and starch were determined by method of [2].

RESULT AND DISCUSSION

Root development: Developments of roots in terms of root depth, number of roots $plant^{-1}$ and dry weight of roots $plant^{-1}$ (Table-1) were maximized in the treatment of linseed + lentil (3:1), the minimum values of these parameters recorded under linseed + barley (5:1). Further, the application of integrated nutrient management (N_3) @ 75% RDN through inorganic + 25% RDN through RDN through vermicompost + biofertilizer (seed coating) + PSB @ 2.5 kg ha^{-1} in soil significantly increased the days to root depth, number of roots $plant^{-1}$ and dry weight of roots $plant^{-1}$ and minimum days for these parameters occurred in the treatment getting RDN (N_1) during the period of study. These results are in accordance with those of [12], [4] and [13].

Quality parameters: The information on oil yield/content of linseed, protein content of lentil and barley for different treatments indicated that the oil content in linseed was significantly influenced by the different treatments over the periods of experimentation (Table-2). Sole cropping showed significantly higher yield as compared to intercropping treatments. However, oil yield/content & protein was significantly highest under linseed + lentil (3:1) in linseed & lentil, linseed + barley (3:1) in barley followed by linseed + lentil/barley (4:1) whereas lowest yield was obtained in the treatment of linseed + barley (5:1) among different cropping systems during two different years. Application of 75% RDN through inorganic + 25% RDN through vermicompost + biofertilizer (seed coating) + PSB @ 2.5 kg ha^{-1} in soil brought about significantly highest oil yield & protein content and lowest values under RDN as well as oil yield & protein might be due to integrated application of fertilizers and organic sources has been also reported by [8], [9] and [3].

Table–1: Effect of Cropping systems and Integrated nutrient management on root development under different treatments.

Treatment	Linseed						Lentil						Barley					
	Root depth (cm)		*Number of roots plant^{-1}*		*Dry weight of roots plant^{-1} (g)*		*Root depth (cm)*		*Number of roots plant^{-1}*		*Dry weight of roots plant^{-1} (g)*		*Root depth (cm)*		*Number of roots plant^{-1}*		*Dry weight of roots plant^{-1} (g)*	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
A. Cropping systems:																		
C_1 Linseed sole	23.5	22.5	26.3	25.4	2.13	2.10	-	-	-	-	-	-	-	-	-	-	-	-
C_2 Lentil sole	-	-	-	-	-	-	30.5	29.3	19.7	18.3	2.65	2.60	-	-	-	-	-	-
C_3 Barley sole	-	-	-	-	-	-	-	-	-	-	-	-	26.3	25.3	32.7	30.2	2.75	2.43
C_4 Linseed + lentil (3:1)	22.7	21.4	24.5	23.5	2.07	2.05	28.3	27.3	18.2	17.3	2.55	2.50	-	-	-	-	-	-
C_5 Linseed + barley (3:1)	20.6	19.4	22.9	21.9	1.92	1.85	-	-	-	-	-	-	24.5	24.0	30.4	29.4	2.60	2.54
C_6 Linseed + lentil (4:1)	21.5	20.7	23.5	22.4	1.98	1.90	27.5	26.4	17.4	16.8	2.37	2.24	-	-	-	-	-	-
C_7 Linseed + barley (4:1)	20.0	19.0	21.6	21.4	1.88	1.82	-	-	-	-	-	-	23.1	22.5	29.3	28.3	2.45	2.35
C_8 Linseed + lentil (5:1)	21.2	20.1	22.7	22.0	1.96	1.89	25.8	25.2	15.8	15.0	2.22	2.15	-	-	-	-	-	-
C_9 Linseed + barley (5:1)	19.3	18.3	20.4	19.4	1.82	1.75	-	-	-	-	-	-	22.6	22.0	28.4	27.4	2.32	2.24
SE ± (diff)	0.64	0.59	0.76	0.69	0.07	0.05	0.39	0.35	0.17	0.15	0.09	0.07	0.45	0.42	0.79	0.72	0.07	0.05

CD (P=0.05)	1.62	1.34	1.50	1.35	0.14	0.11	0.76	0.71	0.34	0.31	0.18	0.15	0.91	0.85	1.64	1.48	0.14	0.10
B. Integrated nutrient management:																		
N_1	20.0	19.0	21.6	20.5	1.89	1.80	26.0	25.6	16.7	15.3	2.24	2.18	22.7	22.5	28.7	28.3	2.45	2.39
N_2	21.3	21.2	23.7	22.1	2.00	1.86	27.4	26.8	17.6	16.8	2.40	2.20	24.3	24.9	30.4	29.8	2.59	2.46
N_3	22.4	22.6	24.3	23.0	2.03	2.00	28.7	27.9	18.2	17.2	2.62	2.57	25.8	25.4	31.4	30.0	2.72	2.62
SE ± (diff)	0.42	0.37	0.46	0.34	0.03	0.02	0.31	0.28	0.09	0.7	0.04	0.03	0.22	0.20	0.51	0.46	0.04	0.03
CD (P=0.05)	0.86	0.68	0.97	0.69	0.06	0.04	0.63	0.57	0.18	0.15	0.09	0.06	0.45	0.41	1.05	0.97	0.10	0.07

N_1 : *RDN.* **N_2 :***75% RDN through inorganic + 25% RDN through vermicompost.*

N_3 : *75% RDN through inorganic + 25% RDN through vermicompost + bio-fertilizer (seed coating) + PSB @ 2.5 kg ha^{-1} in soil.*

Table :2– Effect of Cropping systems and INM on Oil yield in linseed and Protein content in lentil & barley under different treatments.

Treatment	Oil Content (%)		Oil Yield (kg ha^{-1})		Protein content in Lentil (%)		Protein content in Barley (%)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
A. Cropping systems:								
C_1 Linseed sole	39.20	39.00	415.91	376.74	-	-	-	-
C_2 Lentil sole	-	-	-	-	26.34	25.98	-	-
C_3 Barley sole	-	-	-	-	-	-	14.90	14.88
C_4 Linseed + lentil (3:1)	38.92	38.00	378.30	345.80	26.10	25.65	-	-
C_5 Linseed + barley (3:1)	37.23	37.10	332.83	314.23	-	-	13.13	13.03
C_6 Linseed + lentil (4:1)	36.78	35.98	337.64	322.38	25.00	24.65	-	-
C_7 Linseed + barley (4:1)	35.80	35.35	308.59	293.05	-	-	12.20	12.13
C_8 Linseed + lentil (5:1)	35.00	34.78	315.00	299.10	24.67	23.89	-	-
C_9 Linseed + barley (5:1)	34.87	34.00	278.26	257.72	-	-	12.00	11.96
SE ± (diff)	0.15	0.14	0.64	0.60	0.18	0.15	0.43	0.41
CD (P=0.05)	0.31	0.29	1.29	1.20	0.36	0.30	0.89	0.91
B. Integrated nutrient management:								
N_1	35.56	35.40	301.54	275.41	24.78	24.00	13.23	13.09
N_2	36.47	36.25	332.60	312.47	25.45	25.12	13.97	13.76
N_3	38.42	37.50	378.43	364.42	26.15	26.00	14.88	14.69
SE ± (diff)	0.12	0.16	0.54	0.51	0.20	0.16	0.49	0.48
CD (P=0.05)	0.27	0.33	1.23	1.19	0.40	0.33	0.98	0.99

N_1 : *RDN.*

N_2 :*75% RDN through inorganic + 25% RDN through vermicompost.*

N_3 : *75% RDN through inorganic + 25% RDN through vermicompost + bio-fertilizer (seed coating) + PSB @ 2.5 kg ha^{-1} in soil.*

CONCLUSION

Based on two years of experiment it may be inferred that linseed + lentil (3:1) in linseed & lentil, linseed + barley (3:1) in barley supplemented with 75% RDN through inorganic + 25% RDN through vermicompost + biofertilizer (seed coating) + PSB @ 2.5 kg ha^{-1} in soil showed good potential for sustainable production and proved to be quite remunerative in rainfed alluvial tract of Uttar Pradesh.

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