The Pharma Innovation Journal 2022; 11(4): 1903-1907

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(4): 1903-1907

www.thepharmajournal.com
Received: 17-02-2022
Accepted: 22-03-2022

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Evaluate the effect of inter-cropping ratios on Physio-chemical properties of soil under chickpea-linseed based inter-cropping system

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Abstract
A field experiment was conducted on student instructional farm (SIF) at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the *rabi* season 2019-20 and 2020-21, In the present experiment 24 treatments, were laid out in split plot design with three replications, where allocation of treatments to intercropping system with 8 treatments in main-plots and cultural practices in with 3 treatments in sub-plots. Chickpea and Linseed are shown in different ratio with different cultural practices. Chickpea & Linseed (Variety Avrodhi & Shekhar) intercropping was taken for study. The results seen in terms of Physio-chemical properties of soil, the maximum improvement in physiochemical properties of experimental field (organic carbon, pH, Electrical conductivity, Available Nitrogen, Phosphorus and Potassium) was obtained with I_5 treatment {chickpea + linseed (5:1)} during 2019-20 and 2020-21.

Keywords: Chickpea, linseed, inter-cropping, split plot design, organic carbon, pH

1. Introduction
All Pulses which have been an integral part of Indian diet predominantly vegetarian masses by virtue of being rich in protein and several essential amino acids are most popular among Indian farmers due to their easiness to fit into the crop rotation as well as crop mixture, along with restoration of soil fertility. Chickpea is a cool season crop and general perception is that it requires cooler and longer winter season i.e. also comes under long day plants, and more suited to northern India. It was probably true for the earlier varieties which were bred for cooler, long-season environments confining the chickpea production to northern and central India.
Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops in India and preferred as an important constituent of Indian vegetarian diet. It is most important crop of Rabi season which occupies an area of 3.88 million hectare in the country with an annual production of 3.29 million tonnes and productivity of 8.49 q/h, followed by Myanmar 5.80 lakh hectare, China 0.6 lakh ha and Nepal 0.3 lakh ha. About 95% production of chickpea is from south Asia and 90% which belongs to India. In U.P, it is grown on an area of about 3.20 lakh with a annual production and productivity of 3.34 lakh tonnes and 10.4 q/h, respectively producing about 1.41 tons with the productivity of 911 kg ha-1 (Anon., 2016-17) [1]. This crop is also an integral part of intercropping system for sustainable agricultural production. In spite of its multifarious advantages, its productivity is poor due to several biotic and abiotic factors. Water deficit or moisture stress condition however, not only factor limiting crop production in moisture stress areas but the low nutrient supplying capacity of soil and less fertilizer use also contributes to the large gap between potentially attainable yields and current yields of farmers. Crop management options that efficiently use soil nutrients and moderate amount of nutrients inputs while simultaneously reducing risk are essential for stabilizing and increasing crop production in these areas. The adoption of Chickpea based intercropping system under moisture stress condition not only enhances and sustains the fertility as well as productivity of soil but also improve the nutrient and water use efficiency besides improving the physical, chemical, and biological properties of soil. Intercropping is growing two or more than two crops simultaneously on the same piece of land with a definite row pattern. At present the main objectives of intercropping is higher productivity per unit area of land in addition to stability in production.

Intercropping utilizes resources efficiently and their productivity is increased.

Linseed is an important *rabi* oilseed crop of Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Maharashtra, Odisha and Bihar. There has been a continuous decline in linseed area in the country during the last four decades so to sustain linseed production mainly in irrigated area. The cultivation of linseed is restricted mostly to marginal and sub marginal land under restricted supply of fertilizer and irrigation, lack of improved varieties and untimely sowing, resulting in low crop yield. The linseed crop maintained its increasing trend in productivity while, the area registered the declining trend resulting in stagnant production. The decrease in area might be due to Socio-economic factors as the per capita holding is shrinking owing to population increase, thereby pressing the growers to grow other crops for their sustenance. In addition to this, improper selection of varieties in this region, also affects the crop yield. At present there is a tremendous scope for increasing the yield of linseed with the use of multi-character high yielding varieties. Among the different practices to obtain higher crop yield with suitable agro technique under different agro-climatic zone, The production potentiality of linseed has tremendous potential to increase productivity per unit area by using high yielding.

In the last reporting period – 2009, Canada had the highest share in the production of linseed seed across the world – 43.8%, followed by China – 15.0%, India – 7.95%, USA – 8.89%, and Ethiopia – 7.10%, whereas Europe accounts for 12.1% of this production. Ethiopia's linseed acreage has increased significantly as a result of broad-based research on local varieties and ecotypes, which have been confronted, in terms of their productivity and seed oil content, with the leading varieties supplied from Canada and the USA, the countries being the scientific and financial partners for this project (Wakjira *et al.*, 2004) [15]. In these both countries from the North-American agricultural district of the world, seed yield of linseed is systematically growing, thereby the total share of these two countries in global linseed production exceeds 50%, thus making them leading exporters of this agricultural produce. In Canada, linseed ranks sixth in importance among agricultural crops (Johnston *et al.* 2012) [7].

Intercropping offers an excellent opportunity in sustaining their production through the best use of available resources and inputs by minimizing competition and by providing a barrier to the entry of many biotic pests. Intercropping system has some of the potential benefits such as increased productivity per unit area per unit time, high profitability, improvement in soil fertility, efficient use of resources and reducing damage caused by pests, diseases and weeds (Ghosh *et al.* 2006) [3]. Different intercrops and their spatial arrangement in intercropping have important effect on competition between component crops and their growth (Sarkar *et al.* 2000) [12].

2. Materials and Methods

2.1 Study Site: A field experiment was conducted at field no. 6 Student's Instructional Farm at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the *Rabi* season 2019 and 2020. The experimental field was well drained with uniform topography and assured source of water supply through tube well. The farm is situated in the alluvial belt of the indo gangetic plain of central U.P., India.

2.2 Geographical Location: District Kanpur Nagar is situated in subtropical and semi-arid zone and lies between the parallel of 25°26'and 26°58'north latitude and 79°31' and 80°34' east longitude with an elevation of 125.9 m from sea level in the alluvial belt of Indo- gangetic plains of central Uttar Pradesh.

2.3 Physico-chemical properties of the experimental field

The soil of the experimental field was originated farm alluvial deposits. The soil type and fertility status was determined by the mechanical and chemical analysis of the soil. In order to ascertain Physio-chemical properties of the experimental soil, primary soil samples were drawn randomly up to 15cm depth from different spots of the entire experimental area. A representative soil sample was drawn from these samples, which was subjected to mechanical and chemical analysis to ascertain its Physio-chemical properties. Methods used for the determination of physical and chemical properties of soil and their outcomes are presented in Table 3.2.

Table 1: Procedure followed in Physical and Chemical analysis of experimental soil and their results

Sr. No.	Soil properties	Values (%)		Method of determination	Reference	Remarks
		2019- 20	2020-21			
2.	***Chemical properties***					
a.	Organic carbon (%)	0.41	0.42	Walkley and Black's rapid titration method	Jackson (1967) [6]	Medium
b.	Available N (kg/ha)	209.20	228.75	Alkaline potassium permanganate method	Subbiah and Asija (1956) [14]	Low
c.	Available P (kg/ha)	13.07	13.12	Olsen's calorimetrically method	Olsen *et al.* (1954) [9]	Medium
d.	Available K (kg/ha)	173.76	173.75	Flame photometer method	Jackson (1967) [6]	Medium
e.	Soil pH	7.72	7.70	Electrometric glass electrode method	Piper (1966) [10]	Slightly alkaline
f.	EC (ds/m)	0.131	0.129	Electrometric glass electrode method	Jackson (1967) [6]	-

2.4 Experimental Details: The experiment was laid out, 24 treatment combinations with 3 replications were tested in split-plot design where allocation of treatments to intercropping system with 8 treatments in main-plots and cultural practices in with 3 treatments in sub-plots. The details of treatments along with symbols used are given below:

Main-plot treatments: intercropping systems with 8 treatments *viz.*

1. I_1 - Chickpea Sole
2. I_2 - Linseed Sole
3. I_3 - Chickpea + Linseed (3:1)
4. I_4 – Chickpea + Linseed (4:1)
5. I_5 – Chickpea + Linseed (5:1)
6. I_6-Chickpea + Linseed (4:2)
7. I_7 - Chickpea + Linseed (5:2)
8. I_8 – Chickpea + Linseed (6:2)

Sub-plot treatments: 3 Cultural practices *viz.*

1. C_1 – Farmer Practices

2. C_2 –Weedicide (pre-emergence)
3. C_3 – Dust Mulch at 25 DAS

2.4.1 Details

Number of total plots : 72
No. of plots/replication : 24
No. of main plots/replication : 8
No. of sub-plots/main plot : 3
Gross plot size : 5.0 m x 3.6 m =18 m^2
Row spacing : 45 cm
Crop season : *Rabi*
Crop variety : Chickpea (*Avrodhi)*
Linseed (Shekhar)

2.5 Statistical Analysis: The experiment was laid out in factorial randomized block design and replicated thrice. The data on various characters studied during the course of investigation were statistically analyzed for factorial randomized block design. Wherever treatment differences were significant ("F" test), critical differences were worked out at five per cent probability level. The data obtained during the study were analyzed statistically using the methods advocated by Chandel (1990) [2].

3. Results

3.1 Physico-Chemical Properties of Soil

Physico-Chemical properties of soil are determined before sowing and after harvest of crop during both the year of experimentation. The data pertaining to Physico-Chemical properties of the soil in terms of soil pH and Electrical conductivity (EC) are tabulated in Table 2

Response that different intercropping system effect of Physico-Chemical properties of soil on pH and Electrical conductivity (EC) are influenced during both the year and pooled basis of chickpea + linseed intercropping system. Results reveals that was recorded data showed in Table- of soil collected before sowing and after harvest of crop during both year and pooled basis. However, different intercropping system recorded similar data did not have any major effect on Physico-Chemical properties of the soil during both the year and pooled basis.

3.1.1 Soil pH

It is evident from the data available in Table 1 revealed that different intercropping system and cultural practices in Chickpea + Linseed intercropping system influenced soil pH during both the year and also pooled basis.

1. **Effect of intercropping systems:** Among the intercropping systems **I_5**, Chickpea+ linseed (5:1) row ratio was significantly influenced on pH of the soil during both the year and on pooled basis followed by other intercropping systems.
2. **Effect of Cultural practices:** Similar trend was observed under different cultural practices where no significant different was found among treatments. The interaction effect (different intercropping system and cultural practices) on soil pH was not found significantly during both the year and pooled basis.

3.1.2 Electrical Conductivity (dSm^{-1})

It is evident from the data available in Table 1 revealed that different intercropping system and cultural practices in Chickpea + Linseed intercropping system influenced electrical conductivity during both the year and also pooled basis.

1. **Effect of intercropping systems:** Electrical conductivity slightly varied due to various intercropping system during both the years of study. Among the intercropping systems I_5 Chickpea + linseed (5:1) row ratio was significantly influenced on EC of the soil during both the year and on pooled basis followed by other intercropping systems.
2. **Effect of Cultural practices:** Similar trend was observed under different cultural practices where no significant different was found among treatments. The interaction effect (different intercropping system and cultural practices) on soil EC was not found significantly during both the year and pooled basis.

Table 2: Physico-chemical properties before showing and after harvest of crop during both year

Treatments	Physico-chemical properties											
	Before showing of crop						After harvest of crop					
	pH			EC(dSm^{-1})			pH			EC(dSm^{-1})		
	2019-20	2020-21	pooled	2019-20	2020-21	Pooled	2019-20	2020-21	pooled	2019-20	2020-21	pooled
A. Main Plot												
I_1(sole)	7.2	7.4	7.30	0.31	0.32	0.31	7.4	7.5	7.45	0.32	0.31	0.31
I_2(sole)	7.4	7.3	7.35	0.32	0.33	0.32	7.3	7.4	7.35	0.31	0.32	0.31
I_3(3:1)	6.7	6.6	6.65	0.29	0.31	0.30	6.9	7.2	7.05	0.29	0.32	0.30
I_4(4:1)	7.1	7.2	7.15	0.32	0.33	0.32	7.2	7.4	7.30	0.32	0.34	0.33
I_5(5:1)	7.2	7.4	7.30	0.33	0.33	0.30	7.4	7.5	7.45	0.33	0.34	0.32
I_6(4:2)	7.2	6.9	7.05	0.28	0.31	0.29	7.2	6.9	7.05	0.28	0.32	0.30
I_7(5:2)	7.2	7.4	7.30	0.32	0.32	0.32	6.9	7.3	7.10	0.29	0.32	0.30
I_8(6:2)	7.5	6.9	7.20	0.31	0.31	0.31	7.2	7.2	7.20	0.31	0.32	0.31
B. Sub-Plot												
C_1	6.6	6.8	6.70	0.29	0.31	0.30	7.2	7.2	7.20	0.31	0.31	0.31
C_2	7.2	7.4	7.30	0.32	0.33	0.32	7.4	7.5	7.45	0.31	0.33	0.32
C_3	7.4	7.5	7.45	0.31	0.32	0.31	7.2	7.4	7.30	0.32	0.33	0.32

3.2 Chemical Properties of Soil

Response that different intercropping system effect of Chemical properties of soil on Organic carbon, Available nitrogen, Available phosphorus and Available potassium are influenced during both the year and pooled basis of chickpea + linseed intercropping system. Results reveals that was recorded data showed in Table 3, 4 of soil collected before sowing and after harvest of crop during both year and pooled basis. However, different intercropping system recorded similar data did not have any major effect on Chemical properties of the soil during both the year and pooled basis.

3.3 Organic Carbon (%)
There was little variation in soil organic carbon content between first and second year of experimentation. Organic carbon content in soil increased slightly due to different intercropping system and cultural practices.

1. **Effect of intercropping systems:** Among the intercropping systems I_5, Chickpea + linseed (5:1) row ratio was influenced slightly higher values of organic carbon in soil as compared to its initial value *i.e.* 0.43 and 0.44 and 0.43 percentage on pooled basis. Organic carbon (OC) of the soil during both the year and on pooled basis followed by other intercropping systems.
2. **Effect of Cultural practices:** Similar trend was observed under different cultural practices where no significant different was found among treatments. The interaction effect (different intercropping system and cultural practices) on soil organic carbon was not found significantly during both the year and pooled basis.

3.3.1 Available N, P and K in Soil
Available N, P and K in soil were estimated before sowing and after each harvest of chickpea + linseed intercropping system. It is evident from the data available in Table 3, 4 revealed that different intercropping system and cultural practices in Chickpea+ Linseed intercropping system influenced available nitrogen, phosphorus and potassium in soil during both the year and also pooled basis.

1. **Effect of intercropping systems:** Among the intercropping systems I_5, Chickpea + linseed (5:1) row ratio was recorded significantly higher chemical properties of the soil in terms of available N, P and K in soil during both the year and on pooled basis followed by other intercropping systems.
2. **Effect of Cultural practices:** In case of cultural practices chemical properties showed significant increase, C_2 (weedicide) - the response was recorded significantly higher chemical properties of the soil in terms of available N, P and K in soil during both the year and on pooled basis followed by other cultural practices. Similar trend was observed under different cultural practices where no significant different was found among treatments.

The interaction effect (different intercropping system and cultural practices) on chemical properties of the soil in terms of available N, P and K in soil was not found significantly during both the year and pooled basis.

Table 3: Chemical properties before showing of crop during both year (2019-20 &2020-21)

Treatments	OC (%)			Avai. N (Kgha^{-1})			Avai.P_2O_5 (Kgha^{-1})			Avai.K_2O (Kgha^{-1})		
	2019-20	2020-21	pooled	2019-20	2020-21	pooled	2019-20	2020-21	pooled	2019-20	2020-21	pooled
A. Main Plot												
I_1(sole)	0.400	0.410	0.405	208.35	213.56	210.96	12.81	12.65	12.81	127.56	129.29	128.40
I_2(sole)	0.416	0.426	0.421	216.82	222.03	219.42	12.78	12.82	12.80	126.69	128.42	127.55
I_3(3:1)	0.425	0.435	0.425	211.08	196.29	203.68	12.77	13.08	12.93	127.36	128.32	127.84
I_4(4:1)	0.409	0.419	0.414	221.38	226.58	223.98	13.32	13.16	13.32	128.57	130.36	129.47
I_5(5:1)	0.430	0.440	0.435	223.98	229.19	226.59	13.28	13.59	13.43	132.02	133.79	132.91
I_6(4:2)	0.369	0.379	0.374	192.08	197.29	194.68	11.52	11.83	11.68	117.05	118.67	117.86
I_7(5:2)	0.401	0.411	0.406	209.01	214.21	211.61	12.54	12.85	12.69	121.49	123.17	122.33
I_8(6:2)	0.415	0.421	0.418	203.78	209.01	206.401	12.22	12.54	12.38	127.23	128.99	128.11
B. Sub-Plot												
C_1	0.391	0.401	0.396	216.17	221.38	218.772	12.97	13.28	13.12	126.81	128.58	127.69
C_2	0.415	0.425	0.415	223.38	224.58	223.98	13.31	13.14	13.22	132.88	134.67	133.77
C_3	0.424	0.436	0.430	221.38	226.58	223.98	13.28	13.12	13.20	130.77	132.58	131.68

Table 4: Chemical properties after harvest of crop during both year (2019-20 &2020-21)

Treatments	OC (%)			Avail. N (Kgha^{-1})			Avail.P_2O_5 (Kgha^{-1})			Avail.K_2O (Kgha^{-1})		
	2019-20	2020-21	pooled	2019-20	2020-21	Pooled	2019-20	2020-21	pooled	2019-20	2020-21	pooled
A. Main Plot												
I_1(sole)	0.410	0.420	0.415	208.46	214.26	211.36	12.81	12.75	12.78	127.67	129.39	128.53
I_2(sole)	0.426	0.436	0.431	218.82	222.43	220.62	12.98	12.82	12.90	126.89	128.42	127.65
I_3(3:1)	0.425	0.445	0.435	212.08	196.29	204.18	12.87	13.07	12.97	127.56	128.42	127.99
I_4(4:1)	0.419	0.429	0.424	222.38	227.58	224.98	13.32	13.26	13.29	129.57	130.46	130.01
I_5(5:1)	0.440	0.460	0.450	224.98	229.19	227.08	13.48	13.59	13.53	132.24	132.79	132.51
I_6(4:2)	0.379	0.389	0.384	194.08	198.29	196.18	11.72	11.83	11.77	117.25	119.67	118.46
I_7(5:2)	0.412	0.421	0.416	209.01	215.21	212.11	12.64	12.85	12.74	122.49	123.37	122.93
I_8(6:2)	0.425	0.441	0.433	204.78	209.01	206.89	12.32	12.54	12.43	127.46	128.35	127.90
B. Sub-Plot												
C_1	0.381	0.431	0.406	216.17	221.38	218.77	12.97	13.02	12.99	127.42	128.58	128.00
C_2	0.445	0.435	0.440	224.38	225.58	224.98	13.41	13.24	13.32	132.89	134.67	133.78
C_3	0.434	0.426	0.430	222.38	226.58	224.48	13.38	13.22	13.30	130.87	132.69	131.78

4. Discussion
Results reveal that was recorded different intercropping system did not have any effect on mechanical composition of soil collected before sowing and after the harvest of crops during both years (cf. Table 2 to 4). Response of different intercropping system on *pH, EC and OC* in soil were estimated before sowing and after each harvest of crop. Showed that sowing of linseed sole in intercropping and C_3

dust mulch in culture recorded maximum values in first year before sowing and after harvesting recorded maximum values in sowing of linseed + chickpea (1:4) 2019-20 similar pattern recorded in second year 2020-21 maximum available *pH, EC and OC* in soil under sowing of linseed sole in intercropping and C_3 treatment before sowing and after harvesting followed by linseed + chickpea (1:4) intercropping systems. Similar results reported that Gudadhe *et al.* (2015) [4].

Available Nitrogen (Kg ha^{-1}), Available Phosphorous and Available potassium (Kg ha^{-1}) in soil were estimated before sowing and after each harvest of crop. Showed that sowing of Chickpea + linseed (5:1) recorded maximum values in first year before sowing and after harvesting recorded maximum values in sowing of Chickpea + linseed (5:1) 2019-20 similar pattern recorded in second year 2020-21 maximum Available Nitrogen ($Kgha^{-1}$), Available Phosphorus and Available potassium ($Kgha^{-1}$) in soil under sowing of Chickpea + linseed (5:1) treatment before sowing and after harvesting followed by Chickpea + linseed (5:1) intercropping systems. Similar results reported that Hati *et al.* (2006) [5], Saha *et al.* (2010) [11], Kumawat *et al.* (2012) [8] and Singh *et al.* (2012) [13].

5. Conclusion

From the above results it can be concluded that the maximum improvement in physiochemical properties was found with (I_5) Chickpea + Linseed intercropping system application during crop seasons 2019-20 and 2020-21.

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