www.ThePharmaJournal.com
The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 4476-4481

www.thepharmajournal.com
Received: 08-09-2022
Accepted: 12-10-2022

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Effect of planting geometry and nitrogen level in chickpea + linseed intercropping system on growth, yields and soil microbial properties at subtropical climatic condition

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Abstract
A field experiment was conducted during rabi seasons of 2021- 2022 at Mandsaur university, Mandsaur (M.P.) to identify the suitable cropping system and nitrogen level of chickpea and linseed under intercropping situation and their effect on productivity and profitability along with microbiological properties. The present experiment comprised of four cropping system and four nitrogen level replicated thrice in a two factor RBD by using F test. Results revealed that among the sole cropping significantly maximum growth attributes, growth analysis, number of nodules, nodules dry weight, yield attributes and yields, soil available nutrients (N 235, P 15.75 and K 338.75 kg ha^{-1}) and microbial population (rhizobium (9.2 $x10^7$ CFU), azotobacter (12.1 $x10^7$ CFU) and fungi (9.7 $x10^7$ CFU)), except actinomycetes were recorded in both crop (Chickpea and Linseed) as against Chickpea + Linseed (1:1) and Chickpea + Linseed (1:2). Similar trends were also showed under nitrogen level where crops (Chickpea and Linseed) received nitrogen 60 kg ha^{-1} being at par with nitrogen 40 kg ha^{-1} did produce significantly maximum growth, yields, profit and soil available nutrients (N 252.50, P 15.75 and K 350 kg ha^{-1}) alongwith microbial population *viz.*, rhizobium (9.6 $x10^7$ CFU), azotobacter (13.9 $x10^7$ CFU) and fungi (9.5 $x10^7$ CFU) and minimum actinomycetes (5.6 $x10^7$ CFU), whereas crop received no nitrogen did inferior. As its legume in nature and intercrops with oil seed crop, so it is highly eco-friendly and useful for sustainable agriculture besides maintain health of soil.

Keywords: Chickpea + linseed intercropping, growth analysis, soil available nutrients and microbial population

Introduction
Chickpea or gram is the most important winter grain legume in India belonging to family Fabaceae and is the third most important pulse crop that plays a vital role in global agricultural economy. Chickpea constitutes 38% area and 50% production of pulses in India. Chickpea area of the country has risen from 7.57 million hectare in 1950-51 to 9.56 million hectare in 2019-20. While, linseed (*Linum usitatissimum* L.) is one of the important oilseed crop of the world from very beginning of the human civilization. linseed is grown in a total area of about 2.533 million hectares with a production of about 1.40 lakh metric tonnes. Madhya Pradesh has largest growing area (0.978 lakh ha) and production (0.54 lakh tones) with 561 kg/ha productivity (Ministry of Agriculture, 2020) [14].
Intercropping is an effective approach for boosting the production and quality productivity of crop agricultural practices by cultivating two or more economic dissimilar crop species in distinct row combinations simultaneously on the same piece of land. This practice increased diversity in the cropping system (Bahadur *et al.*, 2016) [5]. Chickpea (*Cicer arietinum L.*) and linseed (*Linum usitatissimum* L.) are grown in sole as well as in mixed stands because of their diverse morphology, growth rhythm and similar climatic requirements. Chickpea is traditionally grown as a mixed crop with several crops like mustard, linseed, barley etc. without taking into consideration of spatial row arrangement. Amongst them, chickpea + linseed are one of the most important cropping systems of Central India. (Rama rao and Chandra nath 2019) [16]. Cultivation of linseed (*Linum ussitatisimum* L.) is gaining momentum due to increase in awareness among urban population about their health. Both these crops may form a perfect combination for improving their productivity and profitability. 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) [10].

Little information is available regarding the competition behavior in chickpea + linseed system. Magnitude of competition also varies with the agro-climatic conditions. Further, both the crops differ in their nutrient absorption behavior and chickpea being a pulse crop may supplement nitrogen requirement of the component crops. Keeping these aspects in view, the present investigation was planned to find out the appropriate row ratio and nutrient management strategy for chickpea–linseed intercropping system (Tanwar *et al*. 2011) [19]. The soil microbial biomass may vary from cropping sequence, soil types and soil management. Soil enzymes are primarily of microbial origin (Bandick and Dick, 1999) [6] which catalyze all biochemical reactions in soil, and are an integral part of nutrient cycles (Acosta-Martinez *et al.*, 2008; Bandick and Dick, 1999) [6]. Therefore, the present study was carried out to evaluate performance, uptake and used efficiency of nutrients of chickpea and linseed along with microbiological properties under intercropping system. Therefore, The present investigation was carried out with the objectives to study the interactive effect of planting geometry and nitrogen level in chickpea + linseed intercropping system on growth, yields and soil microbial properties at Malwa region

Materials and Method

Experimental details and soil description

A field experiment was conducted during the *rabi* season of 2021-2022 at crop research station, Mandsaur University, Mandsaur Madhya Pradesh. The regions located at latitude 24.0752° N and longitude 75.0312° E, 379 m above mean sea level. The minimum temperature follows the same trend as of maximum temperature, though the lowest temperature was 4.81 ^{0}C during the third week of January. The mean weekly maximum relative humidity was 93.29 which were recorded in first week of January and the minimum relative humidity was 19.00 during the third week of March. The total average rainfall received during crop period was 4.65 mm. The experimental field was black cotton soil in texture, (Bouyoucos hydrometer method) and slightly alkaline in reaction (pH 7.8, Glass electrode pH meter). It was low in organic carbon (0.470%), available nitrogen (140.0 kg/ha) and available phosphorus (7.0 kg/ ha) but high in available potassium (316.0 kg/ha) with an electrical conductivity (0.44, Method No.4, USDA Hand Book No. 60, Richards, 1954). All the physic-chemical properties were analyzed as per the slandered procedures given by Jackson (1973) [22]. The treatments comprised four cropping system viz., chickpea+ linseed, sole chickpea and sole linseed, chickpea + linseed (1:1) and chickpea + linseed (1:2). and four fertility levels 0 kg ha^{-1} N, 20 kg ha^{-1} N, 40 kg ha^{-1} N and 60 kg ha^{-1} N, replicated thrice in a factorial randomized block design. The crop was grown as per agronomic package of practice with varieties Vishal G - 87207 (Chickpea) and JLS 73 (Linseed) with the spacing (rows) of 45 cm. The seeds were placed manually in the furrows at a plant to plant distance of 10 cm with a seed rate of 100 and 45 kg ha^{-1} for chickpea and linseed, respectively and sown on 01 November 2021. Two hand weeding were done manually with the help of khurpi for controlling weeds, first at 40 days after sowing and second at 65 days after sowing. Irrigation applied just after sowing. Moreover, 4 irrigations were applied with crop water requirement at critical stages.

Data collection

Observations on various growth parameters viz. plant height (cm), number of branches/plant, dry matter accumulation g/plant were recorded at harvest stage in both crop and number of nodules, dry weight of nodules, CGR and RGR 105day and 75-105 days respectively, and yields were recorded by using standard method.

Soil sampling and analysis

Chemical analysis

Initial composite soil samples of the whole experimental field and the subsequent soil samples were collected with the help of a spade and auger from 0-15, 15-30 and 30-45 cm depth of each individual plot after completion of the experimentation year wise for soil physical as well as chemical and biological properties analysis. Furthermore, available nitrogen was estimated by alkaline $KMnO_4$ method (Subbaiah and Asija, 1956) [23], available phosphorus content of soil was determined by the method described by Olsen *et al*. (1954) [24] and available potassium content of soil was determined by the method described by Hanway and Heidel, (1952) [25]

Biological analysis

Numbers of soil culturable Rhizobium, Azotobacter, fungi and actinomycetes were counted at the maturity stage. Soil cores near the plant roots were collected with an auger. The top 1 cm soil layer was removed and the remaining soil core (as deep as 0.2 m) was sampled. After air-drying, samples were sieved through a 1-mm sieve. Ten grams of each fresh soil sample was added to 90 ml of sterile distilled water. After homogenization for 30 min, each soil suspension was sequentially diluted and 50 ¼L of the resulting solutions was placed on appropriate isolation culture media. After incubation at 32 °C for 24 hours for Rhizobium and action mycetes, for Azotobacter 32 °C for 48 hours and 28 °C for 24 hours for fungi, the colony forming units (CFU) were counted. Soil bacteria, fungi and action mycetes were cultured on Rhizobium medium, CSA medium, Azotobacter agar medium, PDA medium, respectively.

Statistical analysis

The data obtained were subjected to statistical analysis as outlined by Gomez and Gomez (1984) [11]. The treatment differences were tested by using “F” test and critical differences (at 5 per cent probability).

Results and Discussion

Growth parameters

Growth values of chickpea and linseed increase with advancement in crop age and reached to maximum at harvest stage (Table 1.a and 1.b).The growth attributes of chickpea as well as linseed was influenced significantly by the planting patterns and fertility levels. Sole chickpea and sole linseed resulted significantly tallest plant (53.52 cm and 91.46 cm), number of branches (9.73 and 8.56) and dry weight (109.85 g and 38.70 g), than their intercropping at harvest stage. Sole chickpea recorded highest number of nodules (38.80) and dry weight of nodules (93.03 mg) as compared to intercropping system 1:2 (33.35 and 88.99 mg) and 1:1 (31.65 and 88.06 mg). It might be due to better availability of nutrients and moisture to the crop and less competition for natural resources as evident from the beneficial effects on the crop growth. These results were in the conformity with the findings of Kumar *et al*. (2015) [13]

Although, chickpea and linseed significantly higher plant height (54.40 cm and 94.27 cm), number of branches (10.28 and 9.06) and dry weight (111.72 gm and 41.37 gm) and sole chickpea highest number of nodules and dry weight of nodules recorded with high fertility level 60 kg ha^{-1} as compared to low fertility level 20 kg ha^{-1} and 0 kg ha^{-1} N. The planting patterns influence the days taken to attain 50% flowering and maturity. The fertility levels also alter the days taken to 50% flowering and maturity in chickpea. Increase in fertility levels which was significant upto 20 kg ha^{-1} alter the maturity stage but the crop of linseed experienced prolong period to attain the stages with increase in fertility levels which was significant up to 60 kg ha^{-1}. However, the maturity of linseed also remained unaffected statistically. Sarkar *et al.* (2000) [17] and Sharma and Goswami (2010) [18] also reported that similar results in chickpea + linseed intercropping system.

Table 1(a): Effect of planting patterns and fertility levels on crop growth, yield analysis and days taken of chickpea at harvest

Treatment	Plant height	Branches/ plant	Dry weight/plant	CGR (g/m^2/day)	RGR (g/plant/day)	50% Flowering	75% Maturity
Planting pattern							
Sole Chickpea	53.52	9.73	109.85	2.53	0.018	70.92	136.92
Chickpea + Linseed (1:1)	50.35	9.38	105.11	2.48	0.019	69.39	134.91
Chickpea + Linseed (1:2)	52.25	9.46	106.44	2.50	0.019	70.57	135.24
SEm	0.93	0.17	1.91	0.04	NA	1.25	2.41
CD (P=0.05)	NS	NS	NS	NS	0.001	NS	NS
Fertility level							
Nitrogen 0 kg ha^{-1}	48.90	8.47	101.14	2.45	0.021	68.41	131.58
Nitrogen 20 kg ha^{-1}	51.40	9.56	106.82	2.50	0.019	69.70	135.10
Nitrogen 40 kg ha^{-1}	53.46	9.77	108.86	2.51	0.018	70.67	137.64
Nitrogen 60 kg ha^{-1}	54.40	10.28	111.72	2.56	0.017	72.40	137.73
SEm±	1.07	0.19	2.21	0.05	NA	1.44	2.78
CD (P=0.05)	3.17	0.58	6.53	NS	0.001	NS	NS

Table 1(b): Effect of planting patterns and fertility levels on crop growth, yield analysis and days taken of linseed at harvest

Treatment	Plant height	Branches/ plant	Dry weight/plant	CGR (g/m^2/day)	RGR (g/plant/day)	50% Flowering	75% Maturity
Planting pattern							
Sole Linseed	91.46	8.56	38.70	0.53	0.007	62.25	110.41
Chickpea + Linseed (1:1)	87.38	8.34	31.00	0.32	0.005	62.85	108.76
Chickpea + Linseed (1:2)	89.36	8.43	33.62	0.40	0.006	61.89	109.13
SEm	1.60	0.15	0.65	0.009	NA	1.14	1.95
CD (P=0.05)	N/S	NS	1.92	0.02	NS	NS	NS
Fertility level							
Nitrogen 0 kg ha^{-1}	83.00	7.30	26.45	0.20	0.003	53.60	104.28
Nitrogen 20 kg ha^{-1}	88.05	8.60	33.65	0.38	0.006	58.98	108.14
Nitrogen 40 kg ha^{-1}	92.28	8.82	36.28	0.48	0.007	62.06	111.76
Nitrogen 60 kg ha^{-1}	94.27	9.06	41.37	0.60	0.008	71.68	113.55
SEm±	1.85	0.17	0.75	0.01	NA	1.32	2.25
CD (P=0.05)	5.47	0.52	2.22	0.03	NS	3.91	6.65

Crop growth rate (CGR) and RGR

The data presented in Table 1.a and 1.b revealed that the crop growth rate of the sole chickpea and sole linseed remained significantly superior (2.52 and 0.53 g/plant/day) over other system of intercropping 1:1(2.48 and 0.32 g/plant/day), though the difference was not significant during 75-105 DAS stage. Among the two systems of intercropping the 1:2 recorded (2.50 and 0.40 g/plant/day) remained none significantly superior over 1:1(2.48 and 0.32 g/plant/day) during the stage of 75-105 DAS. Further, fertility level of nitrogen 60 kg ha^{-1} in both crop recorded highest CGR (2.56 and 0.60 g/plant/day) and minimum CGR with 0 kg ha^{-1} N (2.45 and 0.20 g/plant/day) in chickpea and linseed, respectively. But in case of linseed the highest RGR recorded in sole cropping (0.007 g/plant/day) as compared to intercropping system of 1:1 and 1:2 (0.006 and 0.007 g/plant/day) respectively, at the 0 kg ha^{-1} N highest RGR was recorded (0.008 g/plant/day).

Yield attributes

In the both crop chickpea and linseed sole cropping system recorded the higher yield attributes as compared to intercropping system with the high fertility level 60, 40, 20 and 0 kg ha^{-1} N, respectively, (Table 3.a and 3.b). Sole Chickpea was recorded higher number of pods per plant (43.98) at 60 kg ha^{-1} N (52.64), number of grains per pod (6.25) and grain yield per plant (14.60 g) at highest at 60 kg ha^{-1} (15.54g) and at the same fertility level in the intercropping system of Chickpea + linseed in 1:1 and 1:2 higher number of pods per plant (58.30 and 58.90) number of grains per pod (1.50 and 1.54) and grain yield per plant (14.28 g and 14.33. g). While in the linseed Sole linseed was recorded higher number of capsules per plant (43.98) at 60 kg ha^{-1} N (52.64), number of seeds per pod (6.25) and seed yield per plant (0.47 g) at highest at 60 kg ha^{-1} (0.65 g) and at the same fertility level in the intercropping system of Chickpea + linseed in 1:1 and 1:2 higher number of capsules per plant (40.95 and 41.95) number of seeds per pod (5.99 and 6.03) and seed yield per plant (0.41 g and 0.43 g). Similar results were also reported by Padhi *et al*. (2010), Vasu *et al.* (2013) [21], Tanwar *et al.* (2011) [19], Abraham *et al.* (2010) [1] and Kumar *et al*. (2016) [12]

Yield

The grain yield was influenced significantly due to the planting pattern and fertility levels (Table 3.a and 3.b). The sole crop of chickpea and linseed recorded significantly higher grain yield (18.28 q/ha and 7.52 q/ha) than that of their contributions in the intercropping systems. Between the two intercropping combinations of chickpea +linseed, 1:2 (16.43 q/ha and 5.18 q/ha) remained significantly superior over 1:1 (15.17 q/ha and 4.29 q/ha) in terms of the grain yield of chickpea during while the trends were reversed in terms of the grain yield of linseed. The fertility levels increased the grain yield of chickpea up to 60 kg ha^{-1} N (18.78 q/ha), while this increase was significant up to 60 kg ha^{-1} N (7.08 q/ha) in case of linseed. Application of 60 kg ha^{-1} N remained significantly superior over the other fertility levels in all the planting patterns during both the years except 40 kg ha^{-1} N where it did not differ significantly in the two intercropping systems. The highest seed yield was mainly due to higher yield attributes (pods/plant, seed/pod and test weight) associated with sole crops and 60 kg nitrogen per ha. Tanwar *et al.* (2011) [19]; Gan *et al.* (2009) [9]; Bradar *et al.* (2015) and Abraham *et al.* (2010) [1] have also expressed similar View in their studies.

CEY and B:C ratio

The chickpea equivalent yield was influenced significantly due to the planting patterns and fertility levels (Table 2a and 3). The 2:1 intercropping system produced higher chickpea equivalent yield (792.75 kg/ha) though it remained statistically on a par with that of 1:1 (656.48 kg/ha) intercropping system. The chickpea equivalent yield significantly upto 60 kg ha^{-1} (1081.56 kg/ha). The maximum B:C ratio were obtained in case of the 1:2 (3.86) systems of intercropping and 60 kg ha^{-1} application of Nitrogen(3.41) among the various planting patterns and fertility levels. However, application of 60 kg ha^{-1} of Nitrogen (3.41) ended up with slightly higher B: C ratio. Similar findings were also expressed by Sharma *et al.* (1998) and Halvankar *et al.* (2000). Sarkar *et al.* (2000) [17] and Sharma and Goswami (2010) [18] also reported that similar results in chickpea + linseed intercropping system.

Table 2(b): Effect of planting patterns and fertility levels on yield attributes and yield of linseed

Treatment	Pods/plant	Seeds/pod	Seed yield g/plant	Seed yield q ha^{-1}
Planting pattern				
Sole Linseed	43.98	6.25	0.47	7.52
Chickpea + Linseed (1:1)	40.95	5.99	0.41	4.29
Chickpea + Linseed (1:2)	41.95	6.03	0.43	5.18
SEm	0.81	0.11	0.01	0.11
CD (P=0.05)	N/S	N/S	0.04	0.33
Fertility level				
Nitrogen 0 kg ha^{-1}	26.58	3.97	0.22	3.84
Nitrogen 20 kg ha^{-1}	43.47	5.86	0.40	5.63
Nitrogen 40 kg ha^{-1}	46.46	6.85	0.48	6.11
Nitrogen 60 kg ha^{-1}	52.64	7.63	0.65	7.07
SEm±	0.93	0.13	0.01	0.12
CD (P=0.05)	2.75	0.40	0.04	0.38

Soil available nutrients

The cropping pattern significantly influenced the nitrogen, phosphorus and potash kg ha^{-1} contain in soil of chickpea and linseed (Table 3). The soil of sole crop of Chickpea contains higher nitrogen, phosphorus and potash kg ha^{-1} (N- 235, P_2O_5- 15.75 and K_2O- 338.75 kg ha^{-1}) as compared to sole linseed (N- 176.25, P_2O_5- 10.75 and K_2O- 298.75 kg ha^{-1}). In the intercropping combination of chickpea + linseed in the ratio of 1:1 and 1:2, the higher nitrogen, phosphorus and potash kg ha^{-1} was found in combination of 1:1 ratio *viz.* (N- 203.75, P_2O_5- 14.0 and K_2O- 322 kg ha^{-1}). And soil of sole chickpea is superior in nitrogen availability. Sharma *et al.* (2009) was found similar results in a field study was carried out at the Indian Agricultural Research Institute, New Delhi, India to find out the effect of cropping systems on the production and chemical and biological properties of soil. The fertility levels significantly influenced the nitrogen, phosphorus and potash contain in soil of chickpea and linseed. Application of 60 kg ha^{-1} recorded highest (N- 252.50, P_2O_5- 15.75 and K_2O- 350 kg ha^{-1}) in soil of chickpea and linseed. However the lowest phosphorus contains found in soil of unfertilized plot 0 kg ha^{-1} (N- 156.25, P_2O_5- 9.50 and K_2O- 281.25 kg ha^{-1}) in all four cropping pattern. Aggarwale *et al.* (2002) and Dwivedi *et al.* (2015) [7] also support this similar finding.

Table 3: Effect of planting patterns and fertility levels on soil available nutrients, B:C ratio and microbial population of chickpea and linseed

Treatment	Nitrogen kg ha^{-1}	Phosphorus kg ha^{-1}	Potash kg ha^{-1}	B:C ratio	Rhizobium ($x10^7$) cfu	Azotobacter ($x10^7$) cfu	Actinomy-cetes ($x10^7$) cfu	Fungi ($x10^7$) cfu
Planting pattern								
Sole Chickpea	235	15.75	338.75	2.71	9.2	12.1	6.4	9.7
Sole Linseed	176.25	10.75	298.75	1.95	--	7.0	9.5	6.8
Chickpea + Linseed (1:1)	203.75	14	322.50	3.30	8.1	9.1	7.1	8.5
Chickpea + Linseed (1:2)	187.50	11.50	316.25	3.86	7.5	8.9	8.0	7.9

SEm	3.78	0.24	8.18	0.058	0.1	0.18	0.14	0.15
CD (P=0.05)	10.98	0.70	16.79	0.167	0.4	0.54	0.41	0.44
Fertility level								
Nitrogen 0 kg ha^{-1}	156.25	9.50	281.25	2.35	7.0	5.7	10.2	7.0
Nitrogen 20 kg ha^{-1}	185	12.50	312.50	2.94	7.6	7.6	8.3	7.8
Nitrogen 40 kg ha^{-1}	208.75	14.25	332.50	3.12	8.8	10.0	6.9	8.5
Nitrogen 60 kg ha^{-1}	252.50	15.75	350	3.41	9.6	13.9	5.6	9.5
SEm±	3.78	0.24	8.18	0.058	0.1	0.18	1.4	0.15
CD (P=0.05)	10.98	0.70	16.79	0.167	0.5	0.54	4.1	0.44

Microbial population

Microbial population varied significantly due to cropping system and fertility levels (Table 3), except actinomycetes which remained not significant in all level. Sole cropping of chickpea are resulted significantly maximum rhizobium (9.2 x10^{7} CFU), azotobacter (12.1 x10^{7} CFU) and fungi (9.7 x10^{7} CFU) than their sole cropping of linseed and intercropping system of chickpea + linseed, while actinomycetes shown irreversible trends and remained maximum in linseed alone (9.5 x10^{7} CFU). Although, significantly higher maximum rhizobium (9.6 x10^{7} CFU), azotobacter (13.9 x10^{7} CFU) and fungi (9.5 x10^{7} CFU) and minimum actinomycetes (5.6 x10^{7} CFU) were under higher fertility level of 60 kg ha^{-1} N, However, the as compared to 0 kg ha^{-1} N. This may be due to availability of more organic matter or plant biomass for their food and energy in inorganic or combine use of fertilizers treated plots Kaur *et al*. (2013). The actinomycetes population was increase substantially with decrease population of Rhizobium, azotobacter and fungi and reached to maximum under unfertilized plot or 0 kg ha^{-1} N (10.2 x10^{7} CFU). This may be due to poor availability of lignin like compound for the food and energy for actinomycetes sunder other treatments as compare to control. The results were in consonance with the findings of Tilak (2004) [20] and Dwivedi *et al.* (2015) [7].

Conclusion

Despite the fact that other treatments fairly yielded good production but terms of economics and cost benefit analysis the above discussed intercropping combination of chickpea + linseed 1:2 and 1:1 with fertility level of 60 kg ha^{-1} nitrogen were proven cost effective under the present study, as they not only yielded and generated the desired net income but also improve soil health interms of chemical and biological properties.

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