



# Productivity and Profitability of Cropping System and Row Ratio on the Performance of Chickpea (*Cicer arietinum* L.) + Linseed (*Linum usitatissimum* L.) Intercropping System

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

An experiment was conducted to determine the performance of chickpea + linseed intercropping system at crop research center of SVPUA&T, Meerut, Uttar Pradesh. The field trial was laid on sandy clay loam soil with proper drainage facilities, with low levels of available nitrogen and organic carbon, medium levels of phosphorus, potassium, sulphur, and pH that were moderately alkaline, during 2021-22. The experiment comprised of Chickpea and linseed variety Avrodhi and Garima respectively was tested in a split plot design with three replications and 16 treatment combinations consisting 4 intercropping and 4 cropping modules. viz., chickpea sole, linseed sole, chickpea + linseed in ratio of 1:1, chickpea + linseed in ratio of 2:1 and 4 cropping module viz., control without application of any kind of nutrient, inorganic module with the recommended dose of fertilizer, organic module with FYM, *Trichoderma*, seed inoculation by *Rhizobium*, and PSB, and natural module with seed treatment beejamrutha, foliar application of jeevamrutha, and soil application of panchgavya. Among Intercropping system the maximum grain yield, stover yield, biological yield, harvest index and economics was recorded significantly with the combinations of 2:1 Chickpea + Linseed intercropping system. However, under cropping system modules the highest productivity and profitability of these parameters was recorded significantly with inorganic module over rest of the modules.

**Keywords:** Chickpea; linseed; inorganic module; organic module; natural module; intercropping.

## 1. INTRODUCTION

“Chickpea (*Cicer arietinum* L.) is a crucial pulse crop of the semi-arid tropics, with in the rainfed ecology of India. Globally, it's the third most significant pulse crop after dry beans (*Phaseolus vulgaris*) and dry peas (*Pisum sativum* L.). Nutrients such as Zinc (340 mg 100 g<sup>-1</sup>), calcium (190 mg 100g<sup>-1</sup>), magnesium (140 mg 100g<sup>-1</sup>), iron (7 mg 100g<sup>-1</sup>), and phosphorus (340 mg 100g<sup>-1</sup>) are abundant in chickpea as well as it also contains 18–22% protein, 52–70% carbohydrates, 4–10% lipids, 6% crude fibre, and ash. Chickpea is grown on an average of 14.84 M ha area around the world with the production of 15.08 MT and productivity 10.16 q ha<sup>-1</sup> (FAOSTAT, 2020), In India, it is grown on 9.63 million hectares (M ha) area, with 11.91 million tonnes (MT) production and 10.41 q ha<sup>-1</sup> productivity (DoA, C&FW 2020-21). “Among the states, Uttar Pradesh recorded 4th position (after Madhya Pradesh, Rajasthan, and Maharashtra), with an area of 0.57 (M ha) and production of 0.53 MT, average productivity 930 kg ha<sup>-1</sup>” (Agriculture Statistics at a Glance, GoI 2021).

“Linseed (*Linum usitatissimum* L.) also known as flaxseed and is grown for seed, fiber and also for oil extraction mainly in India which contains 20-24% protein and 37-42% oil, Within the world, linseed is cultivated on 3.54 M ha area, 3.37 MT production, and a median yield of 9.51 q ha<sup>-1</sup> (FAOSTAT 2020). In India linseed is cultivated on area of 0.298 M ha, production 0.11 MT, and

5.47 q ha<sup>-1</sup> Productivity (DoA, C&FW 2020-21), In Uttar Pradesh, it's cultivated on 0.18 M ha area, 0.12 MT production, and productivity is 671 kg ha<sup>-1</sup> (Ministry of Agriculture, GoI 2020), In 2014, linseed was approved by Health Canada for a health claim linking the consumption of whole flaxseed to lowered blood cholesterol levels, a serious risk factor for cardiovascular disease. Intercropping is additionally a component of intensive cropping, which is geared toward crop intensification, resulting in maximum utilization of natural resources like rainfall, radiation, irrigation, and soil for higher crop production. “In an intercropping system, nutrient supplement to plant plays a key role to increase crop yields. Chickpea + linseed is one the foremost important cropping systems of Northern parts of India, where the legume and oilseed plays an important role in human dietary and also for maximizing the returns to the farmers by obtaining higher yields than the sole cropping systems” (Li et al., 2023).

## 2. MATERIALS AND METHODS

“An experiment was conducted at CRC farm of the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) located in Indo-Gangetic plains of Western Uttar Pradesh. The soil of experimental site was sandy clay loam in texture, low in available nitrogen and organic carbon, medium in available phosphorus and potassium and slightly alkaline pH. The experiment was carried out with 16 treatments

consisting combination of 4 intercropping viz., chickpea sole, linseed sole, chickpea + linseed ratio 1:1, chickpea + linseed ratio 2:1 and 4 cropping module viz., control, inorganic module with recommended dose of fertilizer, organic module with FYM, *Trichoderma*, seed inoculation by *Rhizobium*, PSB and natural module with seed treatment by beejamrutha, jeevamrutha by foliar application, panchgavya by soil application, were tested in split plot design with 3 replications. Chickpea was taken as a base crop with plating geometry 30 cm x 15 cm. prior to 12 hours of sowing; seed were treated *Rhizobium* inoculation in chickpea. The recommended dose of fertilizer for chickpea 18:40:20:20 kg of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O S per hectare however for linseed 120:40:20:20 kg of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O S per hectare was applied as the time of sowing. Farm yard manure (FYM) was applied wherever needed as per treatment combinations" (FAOSTAT 2020). *Trichoderma* fungus applied with FYM and broadcasted in the treatment plots where ever needed. Panchgavya was given in to two doses first was at the time of field preparing and second with irrigation water. Jeevamrutha was given in four doses, 1<sup>st</sup> dose was given at the time of sowing and then after 21 days interval as a foliar sprays (10%) in the field. Beejamrutha was used as seed treatment of chickpea and linseed. For linseed seed, seed was coated with beejamrutha, mixing by hand, dry well and then sown on filed, but for chickpea, quick dipping of seeds followed by shade dry and then sown on field. Economics of the treatments was computed on the basis of prevailing market price of input and output under each treatment. Data analysis was done as per the standard analysis of variance technique for the experimental designs using SPSS software based programme, and the treatment means were compared at  $P < 0.05$  level of probability.

### 3 RESULTS AND DISCUSSION

#### 3.1 Grain/Seed Yield (kg ha<sup>-1</sup>)

The data presented in table regarding grain yield of chickpea and seed yield of linseed presented in (Table 1) revealed that chickpea grain yield was influenced significantly by both the intercropping and cropping modules. Chickpea sole recorded the highest grain yield (1432 kg ha<sup>-1</sup>), which was significantly higher than both intercropping treatments. Among the both intercropping treatments ratio of 2:1 chickpea + linseed produced significantly higher grain yield (1165 kg ha<sup>-1</sup>) than the ratio of 1:1 chickpea +

linseed (479 kg ha<sup>-1</sup>). In comparison with sole chickpea the intercropping of chickpea + linseed reduced 66 % and 22 % lower yield by 1:1 and 2:1 row ratio, respectively. Seed yield of linseed revealed that it was influenced significantly by the intercropping and cropping modules. Linseed sole recorded the highest seed yield (1419 kg ha<sup>-1</sup>), which was significantly higher with both intercropping treatments. Among the both intercropping treatments ratio of 1:1 chickpea + linseed produced significantly higher seed yield (1233 kg ha<sup>-1</sup>) than ratio of 2:1 chickpea + linseed (755 kg ha<sup>-1</sup>). In comparison with sole linseed the intercropping of chickpea + linseed reduced 13 % and 46 % lower yield in 1:1 and 2:1 row ratio, respectively. This agreement with the findings of Kumar and Nandan (2007), Tanwar et al. (2011), Upadhyay et al. (2012) and Bradar et al. (2015), Singh and Aulakh (2017).

Among the cropping modules in chickpea the highest grain yield was recorded in inorganic cropping module (1004 kg ha<sup>-1</sup>), which was significantly higher than the organic (853 kg ha<sup>-1</sup>) and natural module (787 kg ha<sup>-1</sup>). Whereas the lowest yield was recorded by control (433 kg ha<sup>-1</sup>). On an average 131 %, 96 % and 81 % increase in chickpea yield over control in inorganic, organic and natural module, respectively. Chickpea + linseed 2:1 ratio having less competition for light, space and nutrient between both of the crop hence, chickpea grows well in 2:1 ratio and recorded better yields as compare to 1:1 row ratio. In linseed highest seed yield was recorded in inorganic cropping module (1057 kg ha<sup>-1</sup>) which was significantly higher than the organic module (975 kg ha<sup>-1</sup>) and natural module (794 kg ha<sup>-1</sup>). Whereas the lowest seed yield was recorded by control (582 kg ha<sup>-1</sup>). On an average 81%, 67% and 36 % increase in yield over control in inorganic, organic and natural module, respectively. These finding was also reported by Tripathi et al. (2010) Abraham et al. (2011), Upadhyay et al. (2012), Singh et al. (2018), Gupta et al. (2019).

#### 3.2 Stover Yield (kg ha<sup>-1</sup>)

The data presented in (Table 1) revealed that the stover yield was influenced significantly by the intercropping and cropping modules. Chickpea sole recorded the higher stover yield (2840 kg ha<sup>-1</sup>), which was significantly higher than both intercropping treatments. Among the both intercropping treatments ratio of 2:1 chickpea + linseed produced significantly higher stover yield

(2539 kg ha<sup>-1</sup>) than ratio of 1:1 chickpea + linseed (1080 kg ha<sup>-1</sup>). In comparison with sole chickpea the intercropping of chickpea + linseed reduced 61 % and 10 % lower stover yield in 1:1 and 2:1 row ratio, respectively. Stover yield of linseed was influenced significantly by the intercropping and cropping modules. Linseed sole recorded the highest stover yield (4064 kg ha<sup>-1</sup>), which was significantly at par with chickpea + linseed 1:1 (3997 kg ha<sup>-1</sup>) and the lowest stover yield were recorded in chickpea + linseed 2:1 (2484 kg ha<sup>-1</sup>). In comparison with sole linseed the intercropping of chickpea + linseed 2 % and 39 % lower stover yield in 1:1 and 2:1 row ratio, respectively. Similar findings were given by Tripathi *et al.* (2005), Wasu *et al.* (2013), Lal *et al.* (2017). Among the cropping modules the highest stover yield in chickpea recorded in inorganic cropping module (2046 kg ha<sup>-1</sup>), which was significantly higher than the organic (1786 kg ha<sup>-1</sup>) and natural module (1663 kg ha<sup>-1</sup>). Whereas the lowest stover yield was recorded by control (963 kg ha<sup>-1</sup>). On an average 113 % and 72 % increase in chickpea stover yield over control in inorganic, organic and natural module, respectively. In linseed the highest stover yield was recorded in inorganic cropping module (2904 kg ha<sup>-1</sup>) which was significantly at par with the organic module (2839 kg ha<sup>-1</sup>). Whereas the lowest stover yield was recorded by control (2110 kg ha<sup>-1</sup>). On an average 37%, 34% and 24 % increase in stover yield over control in inorganic, organic and natural module, respectively. Similar result was also found by Ahmed *et al.* (2007), Ravi Kumar (2009), Hanumantappa *et al.* (2015), Jagadeesha *et al.* (2019).

### 3.3 Biological Yield (kg ha<sup>-1</sup>)

The data presented in (Table 1) revealed that the stover yield was influenced significantly by the intercropping and cropping modules. Chickpea sole recorded the higher stover yield (2840 kg ha<sup>-1</sup>), which was significantly higher than both intercropping treatments. Among the both intercropping treatments ratio of 2:1 chickpea + linseed produced significantly higher stover yield (2539 kg ha<sup>-1</sup>) than ratio of 1:1 chickpea + linseed (1080 kg ha<sup>-1</sup>). In comparison with sole chickpea the intercropping of chickpea + linseed reduced 61 % and 10 % lower stover yield in 1:1 and 2:1 row ratio, respectively. In linseed biological yield was influenced significantly by the intercropping and cropping modules. Linseed sole recorded the highest biological yield (5416

kg ha<sup>-1</sup>), which was significantly at par with the chickpea + linseed 1:1 (5298 kg ha<sup>-1</sup>) and the lowest biological yield were record chickpea + linseed 2:1 (3239 kg ha<sup>-1</sup>). In comparison with sole linseed the intercropping of chickpea + linseed 2 % and 40 % lower biological yield in 1:1 and 2:1 row ratio, respectively. Tripathi *et al.* (2005), Kumar and Singh (2006). Among the cropping modules the biological yield of chickpea recorded highest in inorganic cropping module (3896 kg ha<sup>-1</sup>) which was significantly at par with the organic (3879 kg ha<sup>-1</sup>) and in natural module (3487 kg ha<sup>-1</sup>). Whereas the lowest biological yield was recorded by control (2692 kg ha<sup>-1</sup>). On an average 45%, 44% and 29 % increase in biological yield over control in inorganic, organic and natural module, respectively. In linseed the highest stover yield recorded in inorganic cropping module (2046 kg ha<sup>-1</sup>), which was significantly higher than the organic (1786 kg ha<sup>-1</sup>) and natural module (1663 kg ha<sup>-1</sup>). Whereas the lowest stover yield was recorded by control (963 kg ha<sup>-1</sup>). On an average 113 % and 72 % increase in chickpea stover yield over control in inorganic, organic and natural module, respectively. Sune *et al.* (2006) Kumar and Yadav (2007), Gokhale *et al.* (2008), Meena *et al.* (2011).

### 3.4 Harvest Index (%)

The data presented in (Table 1) revealed that the harvest index was influenced significantly by the intercropping and cropping modules. Chickpea sole was recorded the highest harvest index (33.44 %), which was significantly higher with both intercropping treatments. Among the both intercropping treatments ratio of 2:1 chickpea + linseed (31.19 %) significantly at par with the ratio of 1:1 chickpea + linseed (30.19 %). In linseed, sole recorded highest harvest index (26 %) which was significantly higher with both intercropping treatments. Among the both intercropping treatments ratio of chickpea + linseed 1:1 (23 %) significantly at par with chickpea + linseed 2:1 (23 %). Singh and Aulakh (2017), Singh *et al.* (2018). Among the cropping modules harvest index was non-significant in respect of chickpea. Linseed recorded the highest harvest index recorded in inorganic cropping module (20 %) which was significantly at par with the organic module (19%) and in natural module (17 %) harvest index was record. Whereas the lowest harvest index was recorded by control (16 %). Similar result was find by Ahmed *et al.* (2007), Ravi Kumar (2009).

**Table 1. Effect of intercropping cropping module on grain yield stover yield biological yield and harvest index of chickpea and linseed**

Treatments	Chickpea				Linseed			
	Grain yield (kg ha <sup>-1</sup> )	Stover yield (kg ha <sup>-1</sup> )	Biological yield (kg ha <sup>-1</sup> )	Harvest Index	Seed yield (kg ha <sup>-1</sup> )	Stover yield (kg ha <sup>-1</sup> )	Biological yield (kg ha <sup>-1</sup> )	Harvest Index
<b>Intercropping system</b>								
Sole Chickpea	1432	2840	4272	33.44	-	-	-	-
Sole Linseed	-	-	-	-	1419	4064	5416	26.00
Chickpea + Linseed 1:1	479	1080	1559	30.19	1233	3997	5298	23.00
Chickpea + Linseed 2:1	1165	2539	3704	31.19	755	2484	3239	23.08
<b>SEm±</b>	<b>16.35</b>	<b>32.32</b>	<b>48.66</b>	<b>0.47</b>	<b>19.18</b>	<b>56.78</b>	<b>75.37</b>	<b>0.34</b>
<b>CD (P=0.05)</b>	<b>56.57</b>	<b>111.84</b>	<b>168.37</b>	<b>1.64</b>	<b>66.36</b>	<b>196.47</b>	<b>260.81</b>	<b>1.16</b>
<b>Cropping system modules</b>								
Control	433	963	1396	22.63	582	2110	2692	16.21
Inorganic module	1004	2046	3050	24.53	1057	2904	3896	20.25
Organic module	853	1786	2638	23.97	975	2839	3879	18.75
Natural module	787	1663	2450	23.69	794	2692	3487	16.88
<b>SEm±</b>	<b>17.00</b>	<b>35.43</b>	<b>52.41</b>	<b>0.53</b>	<b>20.66</b>	<b>56.70</b>	<b>74.61</b>	<b>0.54</b>
<b>CD (P=0.05)</b>	<b>49.61</b>	<b>103.42</b>	<b>152.98</b>	<b>NS</b>	<b>56.70</b>	<b>165.51</b>	<b>217.76</b>	<b>1.59</b>

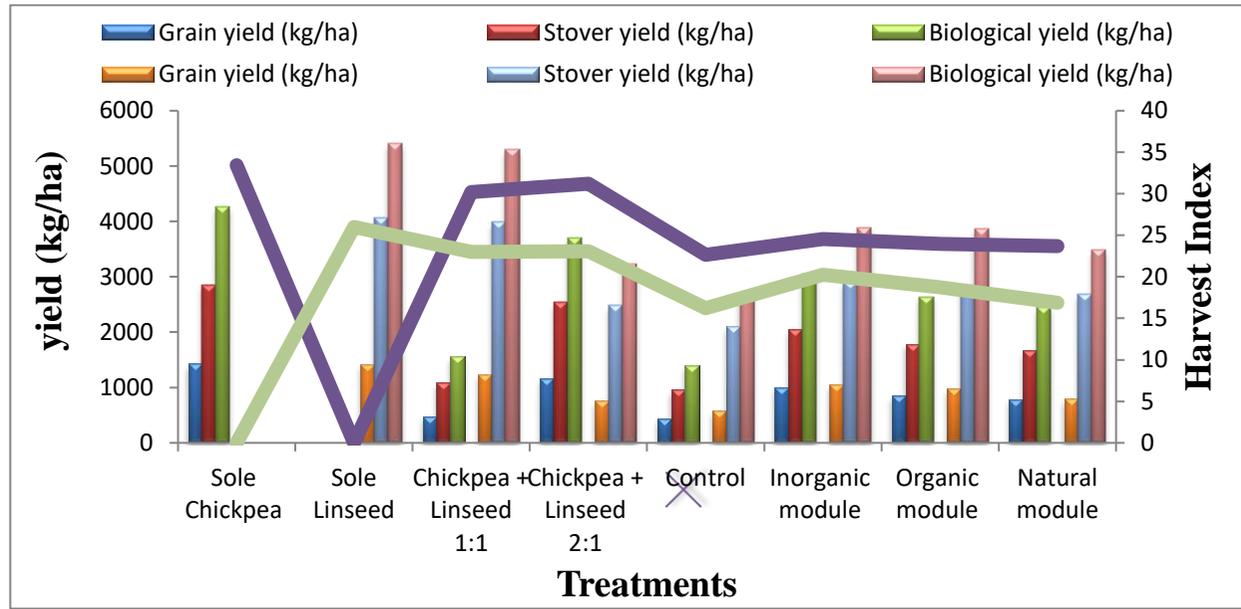


Fig. 1. Effect of intercropping and cropping module on grain yield stover yield biological yield and harvest index of chickpea and linseed

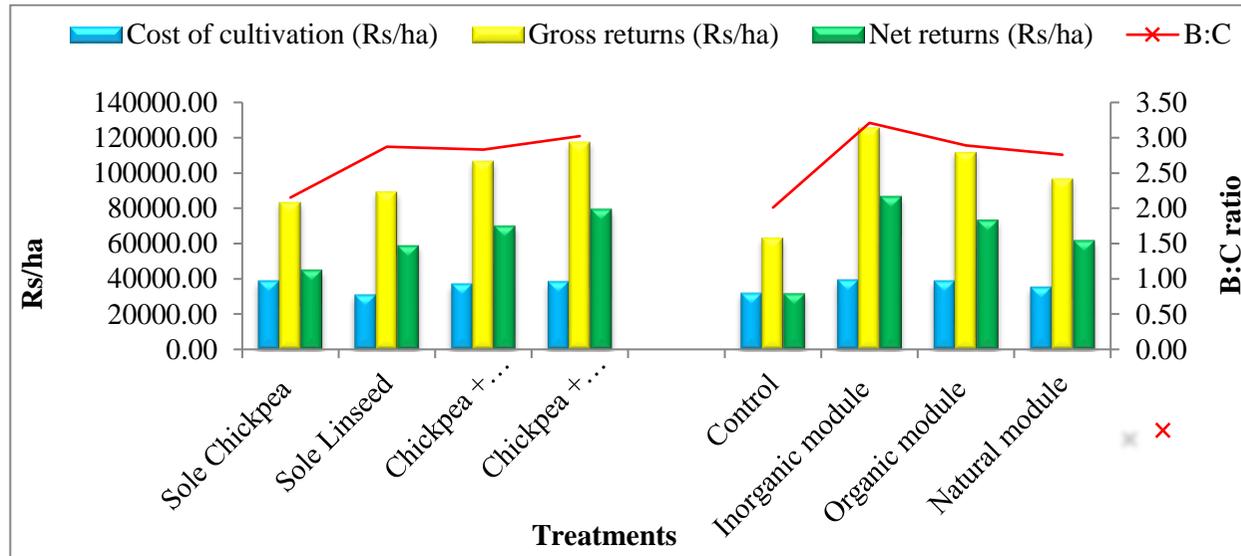


Fig. 2. Effect of intercropping and cropping module on of cost of cultivation (Rs ha<sup>-1</sup>), gross returns (Rs ha<sup>-1</sup>), net return (Rs ha<sup>-1</sup>), B:C ratio of chickpea and linseed

**Table 2. Effect of intercropping and cropping module on CEY and LER**

Treatment	Chickpea equivalent yield (CEY) (kg ha <sup>-1</sup> )	Land equivalent ratio (LER)
<b>Intercropping system</b>		
Sole Chickpea	1432	1.00
Sole Linseed	1419	1.00
Chickpea + Linseed 1:1	1800	1.17
Chickpea + Linseed 2:1	1974	1.32
<b>SEm±</b>	<b>29.15</b>	<b>0.02</b>
<b>CD (P=0.05)</b>	<b>100.86</b>	<b>0.07</b>
<b>Cropping system modules</b>		
Control	1040	1.05
Inorganic module	2105	1.25
Organic module	1868	1.15
Natural module	1612	1.04
<b>SEm±</b>	<b>33.79</b>	<b>0.02</b>
<b>CD (P=0.05)</b>	<b>98.62</b>	<b>0.06</b>

**Table 3. Effect of intercropping system and cropping system module on cost of cultivation (Rs ha<sup>-1</sup>), gross returns (Rs ha<sup>-1</sup>), net return (Rs ha<sup>-1</sup>), B:C ratio of chickpea and linseed**

Treatment	Cost of cultivation (Rs ha <sup>-1</sup> )	Gross return (Rs ha <sup>-1</sup> )	Net return (Rs ha <sup>-1</sup> )	B:C
<b>Intercropping system</b>				
Sole Chickpea	38580.75	83415.14	44834.39	2.15
Sole Linseed	30853.25	89429.29	58576.04	2.87
Chickpea + Linseed 1:1	36978.25	106687.91	69709.66	2.83
Chickpea + Linseed 2:1	38329.50	117431.48	79101.98	3.02
<b>SEm±</b>	<b>686.20</b>	<b>2404.55</b>	<b>1607.96</b>	<b>0.05</b>
<b>CD (P=0.05)</b>	<b>2374.56</b>	<b>8320.85</b>	<b>5564.26</b>	<b>0.17</b>
<b>Cropping system modules</b>				
Control	31731.75	63329.50	31597.75	2.01
Inorganic module	39117.75	125380.03	86262.28	3.21
Organic module	38680.50	111580.02	72899.52	2.89
Natural module	35211.75	96674.28	61462.53	2.76
<b>SEm±</b>	<b>681.14</b>	<b>1666.31</b>	<b>1171.14</b>	<b>0.05</b>
<b>CD (P=0.05)</b>	<b>1988.12</b>	<b>4863.61</b>	<b>3418.33</b>	<b>0.15</b>

### 3.4.1 Chickpea equivalent yield (kg ha<sup>-1</sup>)

The data on CEY presented in (Table 2) revealed that the Chickpea equivalent yield (CEY) Influenced significantly by the intercropping and cropping modules. The highest chickpea equivalent yield (1974 kg ha<sup>-1</sup>) was recorded with intercropping chickpea + Linseed 2:1 and it is followed by 1:1 row ratio (1800 1974 kg ha<sup>-1</sup>). Among the cropping modules the highest chickpea equivalent yield was recorded in inorganic cropping module (2105 kg ha<sup>-1</sup>) which was followed by organic module (1868 kg ha<sup>-1</sup>) and natural module (1612 kg ha<sup>-1</sup>). Whereas the lowest chickpea equivalent yield was obtained under control (1040 kg ha<sup>-1</sup>). Ahlawat *et al.* (2005), Biradar *et al.* (2015).

### 3.5 Land Equivalent Ratio (LER)

The data on LER given in (Table 2) revealed that influenced significantly by the intercropping and cropping modules. The maximum LER (1.32) was recorded under 2:1 row ratio which was significantly superior over other treatments and followed by 1:1 row ratio (1.17). Among the cropping modules the highest land equivalent ratio (1.25) recorded in inorganic cropping modules. This was followed by organic module (1.15) whereas the minimum land equivalent ratio was obtained under control. Similar results were also reported by Kumar and Singh (2006) and Arya *et al.* (2007).

### 3.6 Cost of Cultivation (Rs ha<sup>-1</sup>)

The data presented in (Table 3) revealed that Cost of cultivation influence significantly by the intercropping and cropping modules. The highest cost of cultivation (38580.75 Rs ha<sup>-1</sup>) was recorded with sole chickpea which was significantly at par with the chickpea + linseed 1:1 (36978.25 Rs ha<sup>-1</sup>) and chickpea + linseed 2:1 (38329.50 Rs ha<sup>-1</sup>) intercropping system whereas the lowest cost of cultivation was recorded with sole linseed (30853 Rs ha<sup>-1</sup>). Among the cropping modules the highest cost of cultivation (39117.75 Rs ha<sup>-1</sup>) was recorded with inorganic module which was significantly at par with organic module (38680.50 Rs ha<sup>-1</sup>). The lowest cost of cultivation was recorded by the control (31731.75 Rsha<sup>-1</sup>).

### 3.7 Gross Return (Rs ha<sup>-1</sup>)

The data given in (Table 3) revealed the highest gross returns was recorded with chickpea + linseed 2:1 intercropping (117431.48 Rs ha<sup>-1</sup>) system whereas the lowest gross returns was recorded with sole chickpea (83415 Rs ha<sup>-1</sup>). Among the cropping modules the highest gross return (125380.03 Rs ha<sup>-1</sup>) was recorded with inorganic module whereas the lowest gross return was recorded under control (63329.50 Rs ha<sup>-1</sup>).

### 3.8 Net Return (Rs ha<sup>-1</sup>)

The data on net return (Table 3) recorded with chickpea + linseed 2:1 (79101.98 Rs ha<sup>-1</sup>) intercropping system whereas the lowest net returns was recorded with sole chickpea (44834.39 Rs ha<sup>-1</sup>). Among the cropping modules the highest net returns (Rs 86262.28 ha<sup>-1</sup>) was recorded with inorganic module whereas the lowest net returns was recorded under control (31597.75 Rs ha<sup>-1</sup>). Kumar and Singh (2006), Sharma and Goswami (2010), Ogola et al. (2013), Kalaghatagi et al. (2017).

### 3.9 B:C Ratio

Benefit cost represented in (Table 3) the highest benefit cost ratio was recorded with chickpea + linseed 2:1 (3.02) intercropping system whereas the lowest benefit cost ratio was recorded with sole chickpea (2.15). Among the cropping modules the highest benefit cost ratio (3.21) was recorded with inorganic module whereas the lowest benefit cost ratio was recorded under control (2.01). These findings are in close

agreement with the results of Prasad et al. (2006), Abraham et al. (2010), Ahlawat and Gangaiah (2010).

## 4. CONCLUSION

On the basis of foregoing findings, Among Intercropping system the maximum grain yield, stover yield, biological yield, harvest index and economics was recorded significantly with the combinations of 2:1 Chickpea + Linseed intercropping system. However, under cropping system modules the highest productivity and profitability of these parameters was recorded significantly with inorganic module over rest of the modules. The main advantage of performing organic and natural modules helps in sustaining and improves the soil health.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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