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Research Paper

Chickpea (*Cicer arietinum*)-based intercropping systems in Rajasthan's Hadoti region: Productivity and economic viability

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ABSTRACT

A study was carried out during three successive winter (*rabi*) seasons (2018–19 to 2020–21) at the Agricultural Research Station in Ummedganj, Kota, Rajasthan to determine the productivity and economic viability of intercropping systems based on chickpea (*Cicer arietinum* L.) in the Hadoti region of Rajasthan. Nine various chickpea-based intercropping systems, viz. Sole chickpea; Sole linseed (*Linum usitatissimum* L.); Sole coriander (*Coriandrum sativum* L.); Sole wheat (*Triticum aestivum* L.); Sole mustard [*Brassica juncea* (L.) Czern.]; Chickpea + linseed (6:2); Chickpea + coriander (6:2); Chickpea + wheat (6:2); and Chickpea + mustard (6:2) were investigated in a randomized block design (RBD) with three replications. According to combined statistics, the chickpea + mustard intercropping system had the highest chickpea grain yield and equivalent yield (1,865 kg/ha and 2,574 kg/ha, respectively) when compared to all other intercropping systems. Results of competitive indices revealed that compared to rest of the intercropping system, chickpea + mustard (6:2) recorded significantly higher LER (1.25), MAI (18,462) and SPI (2912 kg/ha), while the lowest land equivalent ratio (LER), monetary advantage index (MAI), system productivity index (SPI) and production efficiency (PE) were recorded in the chickpea + wheat intercropping system. The chickpea + mustard intercropping system yielded values of competition ratio (3.56), aggressivity (-0.05), system profitability index (2912), relative crowding coefficient (13.2), and area time equivalent ratio (1.24), that were sustainable and producible in comparison to other treatments. In terms of economics, compared to all other intercropping and solo crops, the chickpea + mustard intercropping system yielded the chickpea's most significant net returns (₹93,681/ha) and benefit cost (B:C) ratio (3.11). So, for south-eastern Rajasthan, the mustard and chickpea intercropping system is a productive and sustainable system.

***Key words*:** Chickpea, Chickpea equivalent yield, Economic viability, Intercropping systems, Productivity

Chickpea (*Cicer arietinum* L.) is the most important pulse crop in India produced on 9.99 million ha and yields 11.91 million tonnes with an average productivity of 1,192 kg/ha (Anonymous, 2021–22; Meena *et al.,* 2023). The cropping system for sustainable agricultural production includes this crop as an essential component. For the purpose of increasing overall productivity and stability, farmers most frequently cultivate chickpea with other crops including wheat, coriander, barley, safflower, mustard and linseed. Agro-system productivity depends on a variety of biotic and abiotic factors, including cropping patterns, plantation types and fertilization schedules. Intercropping, a historic mixed cropping technique is the practice of growing 2 or more crop species together in the same area. As a form of ecological protection contrary to threats and unpredictable rainfall patterns in areas with limited precipitation, intercropping has traditionally been used to diversify crops in such areas (Kumar *et al*., 2015; Sepat *et al.*, 2019). One such technique, intercropping, has potential for sustainability in terms of overall production and profitability on dryland.

Due to its many benefits, such as improved resource utilization, moisture in the soil, nutrients, minimized risk of ruining crops due to climate-related vagaries, etc., intercropping not only aids in the solution of the problem of producing pulses and oilseeds but also aids in bringing extra revenue to farmers and getting more advantages with a smaller expense of cultivation (Rajput and Kushwaha, 2021). By making the best use of the soil, water, nutrients that are accessible, and natural solar light, it increases agricultural production and profitability (Kumar and Singh,

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2006; Bamboriya *et al.,* 2022). Intercropping legumes with cereals, oilseeds and other crops not only boosts total productivity and income but also enhances the physical characteristics of the soil and boosts soil fertility, all of which help conserve moisture (Dev *et al.,* 2016; Lal *et al.,* 2019; Kumhar *et al.,* 2022). It should be mentioned that the land equivalent ratio, with unity as the crucial value, demonstrates the effectiveness of intercropping for exploiting environmental resources in comparison to monocropping. Despite the fact that intercropping has been used for thousands of years and is common in various regions of all over the world. it is still not fully acknowledged from an agronomic standpoint, and research regarding this topic is much more basic compared to that in monoculture. In order to create intercropping systems that are consistent with the current farming system and to better understand how intercrops work, further research is required.

In the Hadoti region of Rajasthan, the principal crops cultivated during the *rabi* season include chickpea, mustard, linseed, wheat and coriander. Our objective was to devise an optimized intercropping system that promotes productivity, sustainability and compatibility among cereals, oilseeds, pulses, and spice crops. By recommending an optimal row ratio for chickpea alongside other crops, we aim to benefit the local farming community by improving soil health, mitigating the risks of disease and insect pest outbreaks, and alleviating the adverse impacts of unfavourable environmental conditions during the cropping season. This integrated approach not only maximizes space utilization, solar light absorption, and the efficient use of inputs such as fertilizer and water but also fosters a more resilient agricultural ecosystem. Therefore, the stated objective of the current research investigation, which taking into consideration all relevant factors, was to assess the economic feasibility and productivity of a chickpea based intercropping system in the Hadoti region of Rajasthan.

MATERIALS AND METHODS

Present study was carried out during three successive winter (*rabi*) seasons (2018–19 to 2020–21) at the Agricultural Research Station in Ummedganj, Kota (25° 10' 57" N and 75°50' 20" E and 267 metres amsl), Rajasthan. Warm winters and reasonably lengthy summers (which are hot and dry from late March to the end of June) are the defining features of the region's subtropical climate. While the average low temperature in December and January is between 3.5 and 14.7°C, the average maximum temperature in May and June is from 40 to 48.4°C. In the research region, there was 660.6 mm of yearly precipitation, with most of it occurring during the rainy season. The soil of experimental field was clay-loam, relatively deep and well-drained Vertisol, with a soil *p*H of 7.41. The bulk density ($Mg\ m^3$), porosity (%), soil organic carbon (g/kg) and electrical conductivity (dS/m) of the top soil layer (0–15 cm) were estimated to be 1.28, 51.0, 5.10, and 0.65, respectively, at the beginning of the experiment. Additionally, it possessed high levels of exchangeable K (447 kg/ha), low levels of accessible N (239.0 kg/ha) and medium levels of readily accessible P (23.13 kg/ha).

Nine different chickpea-based intercropping systems, viz. Sole chickpea; Sole linseed; Sole coriander; Sole wheat; Sole mustard; Chickpea + linseed (6:2); Chickpea + coriander (6:2); Chickpea + wheat (6:2); and Chickpea + mustard (6:2) were investigated in a randomized block design (RBD) with three replications. 'GNG 1958', 'Pratap Alsi 1', 'RKD 18', 'Raj 4037' and 'NRCHB-101' were the varieties utilized in the experiment for chickpeas, linseed, coriander, wheat, and mustard, respectively. A package of practices developed by the Agriculture University, Kota, Rajasthan was utilized as the basis for the crop management methods. Through the use of standardized methodologies, data on yields, economics and competitive indices of different intercropping and monocropping systems were calculated. To do this, all biometric data gathered throughout the experiment were organized into suitable tables and statistically analyzed using the methods of Gomez and Gomez (1984) recommended for randomized block designs. According to the formulas provided by Verma and Modgal (1983) the chickpea equivalent yield (CEY) was calculated for all crops:

$$\text{CEY (Kg/ha)} = \text{Yield of chickpea} + \frac{\text{Yield of intercrop} \times \text{Price of intercrop}}{\text{Price of chickpea}}$$

Land equivalent ratio (LER)

The proportion of land required to plant a single crop species to produce the same amount of crop at the same management level as intercropping is known as LER (Willey, 1979):

$$LER = \sum_{i}^{m} \frac{Y_i}{Yij} \times \frac{LER - 1}{LER}$$

$Y_{i\,=}$ Per crop yield in intercropping system; Y_{ij} = Per crop yield in single cropping system

Monetary advantages index (MAI) was calculated as (Willey, 1979):

$$MAI = Value\ of\ combined\ yield\ of\ intercrop \times \frac{LER - 1}{LER}$$

Willey (1979) quantified completion ratio (CR) using the given formula:

$$CR = CR_a + CR_b$$

$$CR_a = \left(\frac{LER_a}{LER_b}\right) \times \left(\frac{Z_{ba}}{Z_{ab}}\right)$$

where CRa stands for the intercrop chickpea competition ratio; LER_a is equal to the partial LER of crop 'a,' LER_b = partial LER of crop 'b.'

The income equivalent ratio (IER) was calculated as (Willey, 1979):

$$IER = \frac{Net\ return\ in\ intercropping\ system}{Net\ return\ in\ sole\ cropping\ system}$$

The relative crowding coefficient (K) was determined as (Dewitt's, 1960):

$$K = K_{ab} + K_{ba}$$

$$K = \frac{Y_{ab} \times Z_{ba}}{(Y_{aa} - Y_{ab} \times Z_{ab})} \times \frac{Y_{ba} \times Z_{ab}}{Y_{bb} \times Y_{ba \times Z_{ba}}}$$

where Yaa = main crop 'a' yield as a single crop; Ybb = intercrop 'b' yield as a single crop; Y_{ab} = main crop 'a' yield as intercrop crop cultivated in conjunction with intercrop 'b'; Y_{ba} = intercrop 'b' yield as intercrop crop cultivated in conjunction with main crop 'a'; Z_{ab} = main crop 'a' sown proportion in conjunction with intercrop 'b'; Zba = intercrop 'b' sown proportion in conjunction with main crop 'a'.

McGilchrist (1965) used the following formula to quantify aggressivity (A):

$$A_{ab} = \frac{Mixture\ yield\ of\ 'a'}{Expected\ yield\ of\ 'a'} - \frac{Mixture\ yield\ of\ 'b'}{Expected\ yield\ of\ 'b'}$$

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

where Yaa = main crop 'a' yield as a single crop; Ybb = intercrop 'b' yield as a single crop; Y_{ab} = main crop 'a' yield as intercrop crop cultivated in conjunction with intercrop 'b'; Y_{ba} = intercrop 'b' yield as intercrop crop cultivated in conjunction with main crop 'a'; Z_{ab} = main crop 'a' sown proportion in conjunction with intercrop 'b'; Zba = intercrop 'b' sown proportion in conjunction with main crop 'a'.

Area time equivalent ratio ATER

To calculate the ATER, Hiebsch and Macollam (1980) arrived at the following formula:

$$ATER = \frac{L_A \times T_A + L_B \times T_B}{T}$$

where T is the overall length of the intercropping system; L_A and L_B are the partially LER of crops A and B; T_A and T_B are the duration of crops A and B, respectively.

System productivity index (SPI)

Using the following formula, Odo (1991) calculated the SPI to determine the best intercropping system for increasing system production:

$$System\ productivity\ index\ (SPI) = \left(\frac{S_A}{L_B} \times L_b\right) + S_a$$

where S_A and L_B represent the crops A and B average yields in a sole crop; S_a and L_b represent the mean yields in combined.

RESULTS AND DISCUSSION

Grain yield and chickpea equivalent yield

The 3 years (2018–19 to 2020–21) of pooled data from the experiment demonstrated that the grain production of chickpea, linseed, coriander, wheat, and mustard has been greater in the solo cropping arrangement than the intercropped system in each of the different chickpea-based intercropping systems. The solo cropping system's higher plant density and the absence of companion crop competition are likely to be the causes of this disparity. The intercropping system of chickpea and mustard produced the highest yield of chickpea (1,865 kg/ha), followed by chickpea and coriander (1,744 kg/ha), chickpea and linseed (1,750 kg/ha), and chickpea and wheat (1,642 kg/ha). Similar to this, in comparison to the other intercropping systems, the chickpea + mustard intercropping system produced a much higher chickpea equivalent yield (2,574 kg/ha). This could be because of that chickpea and mustard had a complementary connection, which allowed the crops to utilize resources like space, nutrients, and light more efficiently without running out of any of them because they have different growth cycles and time frames. Compared to intercropping treatments, solo chickpea and intercrops (linseed, coriander, wheat and mustard) produced higher grain yields. This may be owing to monocropping systems have a more uniform environment that causes less disturbances to the habitat.

Additionally, improved soil health with a higher percentage of legumes in intercropping may improve the uptake of macro and micronutrients, therefore nutrients are important in boosting crop yield. The improvements in chickpea equivalent output under intercropping systems may be attributed to favourable microclimatic conditions that encouraged improved crop growth and ultimately higher yield. The higher total productivity under intercropping systems compared to solitary cropping may be attributed to the additional production benefit owing to intercropping as well as the greater economic value of intercropping (Sheoran *et al.,* 2010; Bana *et al*., 2016; Kumhar *et al.,* 2022). Similar results have been given by Das *et al.* (2017) who reported that greater chickpea-equivalent yields from intercropping than from corresponding monocrops were due to higher total productivity from making effective use of resources. These findings were agreed upon by Ahalawat and Gangaiah (2010), Tanwar *et al.,* (2011), Lal *et al.,* (2019) and Chavda *et al.,* (2023).

Competitive indices of intercropping systems based on chickpeas:

Land equivalent ratio (LER), Monetary advantage index

(MAI), Income equivalent ratio (IER), System productivity index (SPI) and Production efficiency (PE): A span of 3 years of pooled data revealed that different chickpea-based intercropping systems had an impact on LER, MAI, IER, SPI and PE (Table 1). When compared to the other chickpea-based intercropping treatments, the chickpea + mustard (6:2) system had the highest LER (1.25), MAI (18462) and SPI (2912 kg/ha), while the chickpea + wheat intercropping system had the lowest LER, MAI, SPI and PE. The solitary wheat system, when compared to sole and intercropping systems, reported the significantly highest system production index (3536 kg/ha). When compared to the intercropping systems of chickpea + linseed and chickpea + wheat, data further showed that the maximum IER and PE were observed under the chickpea + coriander and mustard combinations. An increase in LER in the chickpea + mustard intercropping treatment suggested a yield benefit over monocropping owing to more intense land utilization. Previous studies on the advantages of an intercropping system over a single crop reported by Awasthi *et al.,* (2011) and Dhaka *et al*., (2014). The intercropping system with the chickpea and mustard had the highest MAI, IER and SPI, followed by chickpea and coriander because of the higher yield and selling price of the mustard and coriander. In the end, the MAI or IER represented this increased return in terms of net income. These finding were corroborated by the work of Lal *et al.,* (2013), Poddar *et al*., (2017), and Mishra *et al.,* (2001).

Competition ratio (CR), Aggressivity (A), Relative crowding coefficient (RCC), Area time equivalent ratio (ATER) and System profitability: The data in Table 2 illustrated the competitiveness, aggression, relative crowding coefficient, area time equivalent ratio and system profitability of solo, and intercropping systems based on chickpeas. All of the intercropping systems were more competitive than chickpea, according to the values of CR and aggressivity (A); the highest values of CR and aggressivity were estimated for the chickpea + linseed and chickpea + wheat intercropping systems, respectively. The chickpea + mustard intercropping system had the lowest CR and aggressivity values, whereas chickpea + coriander had the highest. This suggests that chickpea + mustard is more productive than the other treatments. The component crops' aggressivity value also influences how competitively strong they are in an intercropping system. The CR results confirm the findings on aggressivity, which showed that all of the intercrops proved more aggressive in comparison to chickpea. The chickpea with mustard and coriander intercropping treatment was superior to wheat and linseed among the various intercropping treatments. The intercrop and main crop were complementary to one another, as evidenced by the relative crowding coefficient (K) value of

Table 1. Effect of various chickpea-based intercropping systems on productivity and yield when combined with oilseeds, spices, and cereal

Treatment	Seed yield (kg/ha)		Chickpea equivalent yield (CEY) (kg/ha)	Land equivalent ratio (LER)	Monetary advantage index (MAI)	System productivity index (SPI)	Income equivalent ratio (IER)	Production efficiency (PE) kg/ha/day
	Chickpea	Intercrop		–	–	–	–	–
Sole chickpea	2,346	–	2,346	1.00	–	2,346	–	19.23
Sole linseed	1,360	–	1,348	1.00	–	1,360	–	10.37
Sole coriander	1,785	–	2,234	1.00	–	1,785	–	21.28
Sole wheat	3,536	–	1,412	1.00	–	3,536	–	11.12
Sole mustard	1,726	–	1,594	1.00	–	1,726	–	13.07
Chickpea + Linseed (6:2)	1,750	322	2,070	0.99	-1,073	2,306	0.84	15.92
Chickpea + Coriander (6:2)	1,744	576	2,459	1.07	5,476	2,503	2.57	23.42
Chickpea + Wheat (6:2)	1,642	843	1,976	0.94	-4,298	2,202	0.85	15.56
Chickpea + Mustard (6:2)	1,865	771	2,574	1.25	18,462	2,912	2.52	21.10
SEm±	–	–	34.97	0.02	1,053	41.6	0.04	0.284
CD (P=0.05)	–	–	102.82	0.05	3,097	122.3	0.12	0.835

the chickpea + mustard (1.62) being >1. Intercropping these crops with chickpea produced higher ATER values of 1.24 and 1.02, respectively. This is because mustard and coriander exploited time and space with greater efficiency than chickpea performed. The ATER score for the wheat and linseed intercropping system with chickpea was <1, indicating less efficient use of space and time, which might be explained by the longer duration of wheat and linseed than chickpea. The chickpea + coriander system was predicted to have the highest system profitability (₹841.09/ha/day), followed by the chickpea + mustard system (767.87/ha/day), and then all single and intercropping systems.

This shows that the intercropping system was able to produce its maximum yield in a shorter amount of time. In a crop combination setting, the relative crowding coefficient and aggressivity values suggested that intercrop was the dominating species (Ahlawat *et al.,* 2005). According to earlier studies on intercropping (Tanwar *et al.,* 2011; Poddar *et al.,* 2017), RCC was higher in intercropping systems than in alone cropping. All treatments had ATER values that were less than LER values, which demonstrates that resource use was overestimated. In contrast to LER, ATER has no issues with overestimating resource usage. The benefits of the intercropping system were demonstrated by higher ATER values in the chickpea + mustard and chickpea + coriander combinations. It might be explained by the fact that the intercropping systems of chickpea + mustard and chickpea + coriander provide better yields than those of other intercropping and solo crops. These findings corroborate those reported by Imran *et al*., (2011), Das *et al.,* (2017) and Chavda *et al.,* (2023).

Economics

Economics-wise, there was a significant change in the net return and B: C ratio when linseed, coriander, wheat and mustard were intercropped with chickpea. In comparison to the other treatments of chickpea equivalent yield, the chickpea + mustard intercropping system yielded considerably greater net returns (₹93,681/ha) and B:C ratio (3.11). The intercropping systems of chickpea with mustard and coriander showed their superiority in terms of economic sustainability over monoculture cropping and other intercropping systems. The lowest net returns (₹34,445/ha) and B:C ratio (1.16) of chickpea equivalent yield were attained by sole linseed (Table 2). This may be because the intercropping system produced a larger yield of chickpeas equivalent than other intercropping and sole cropping systems, which had a positive influence on yield. Singh *et al.,* (2019) and Rajput and Kushwaha (2021) also determined that the chickpea with mustard combining system was the greatest viable one due to its greater net returns and better B:C ratio.

Table 2. Effect of various chickpea-based intercropping systems on competitive indices and economics when combined with oilseeds, spices, and cereal

Treatment	Competition ratio (CR)	Aggressivity (A)	Relative crowding coefficient (RCC)			Area time equivalent ratio (ATER)	System profitability (₹/ha/day)	Net returns (₹/ha)	B:C ratio
			Chickpea	Intercrop	System				
Sole chickpea	1.00	–	–	–	–	1.00	677.65	82,674	2.75
Sole linseed	1.00	–	–	–	–	1.00	264.96	34,445	1.16
Sole coriander	1.00	–	–	–	–	1.00	731.37	76,794	2.61
Sole wheat	1.00	–	–	–	–	1.00	294.74	37,433	1.28
Sole mustard	1.00	–	–	–	–	1.00	378.24	46,146	1.57
Chickpea + Linseed (6:2)	6.32	0.14	6.08	0.62	3.76	0.94	534.11	69,434	2.30
Chickpea + Coriander (6:2)	4.64	0.05	6.14	0.96	5.80	1.02	841.09	88,314	2.91
Chickpea + Wheat (6:2)	5.91	0.11	5.18	0.63	3.26	0.91	513.52	65,216	2.13
Chickpea + Mustard (6:2)	3.56	-0.05	7.99	1.62	13.02	1.24	767.87	9,3681	3.11
SEm±	0.149	0.0092	0.42	0.02	0.501	0.01	13.74	1,688.70	0.06
CD (P=0.05)	0.440	0.0270	1.24	0.06	1.475	0.04	40.39	4,965.74	0.16

CONCLUSION

Based on a 3-years field study involving oilseeds, spices, and cereals, it can be concluded that an intercropping system consisting of chickpeas and mustard is more favourable than any other intercropping or monocropping system. In order to boost profitability and productivity in south-eastern Rajasthan, the intercropping system of chickpea + mustard (6:2) may be suggested as being both ecologically as well as economically viable.

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