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Effect of row ratios and organic nutrient management on productivity and economics of Indian mustard (*Brassica juncea*) + chickpea (*Cicer arietinum*) intercropping system

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ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2021–22 and 2022–23 at the research farm of Indian Agricultural Research Institute, New Delhi to find out the suitable cropping system with optimum row ratio and nutrient management practice in Indian mustard [*Brassica juncea* (L.) Czern.] + chickpea (*Cicer arietinum* L.) intercropping system. Cropping systems i.e. mustard sole; chickpea sole; mustard + chickpea 2:5; mustard + chickpea 5:2 was taken as main plots. Nutrient management practices i.e. control; 60 kg Nitrogen/ha; 20 kg Nitrogen through farmyard manure + leaf manure; 20 kg Nitrogen through farmyard manure + leaf manure + microbial consortia were taken as sub-plots to attain a higher degree of precision. It was observed that though the crop yields of individual crops of mustard and chickpea were the highest in sole crop, but yield of intercropping system in terms of mustard equivalent yield was found to be the highest for mustard + chickpea 5:2 row ratio. Yields of both mustard and chickpea were observed to be the highest in the plots treated with combination of organic manures and microbial consortia i.e. 20 kg nitrogen through farmyard manure + leaf manure @4 t/ha + microbial consortia. Highest gross returns, net returns and benefit-cost ratio were found in mustard + chickpea 5:2 row ratio. Analysis of intercropping indices revealed the highest intercropping advantage in mustard + chickpea 5:2 row ratio when treated with organic manures and microbial consortia. Intercropping systems had land equivalent ratio more than unity, depicting advantage. Aggressivity values showed mustard crop was dominant over chickpea.

Keywords: Economics, Equivalent yield, Nutrient management, Row ratios

Intercropping provides significant advantages in land use efficiency, crop productivity and monetary returns as a result of effective use of solar energy and inputs as compared with sole cropping under diverse agroecological situations (Mucheru-Muna *et al*. 2010). Indian mustard [*Brassica juncea* (L.) Czern.] with chickpea (*Cicer arietinum* L.) is a prominent intercropping system throughout the entire Indian subcontinent under dryland conserved moisture conditions. When these two crops are planted in specific proportions and row ratios, the scientific intercropping method boosts productivity per unit area per unit time (Ramarao *et al*. 2020). In order to maximise intercropping advantage, the level of complementarity between the components must be maximized while intercrop competition must be minimized (Willey 1990). Therefore, judging a proper row ratio to minimize shading effect is important. The intercropping of these crops, i.e. pulses and oilseed crops, appears to be the most practical, economically sound and socially acceptable method among the several ways used to increase the yield of oilseed crops (Viswanathan *et al*. 2020). Chickpea is a highly water efficient and climate resilient crop that can be grown in drought prone areas. It helps in soil fertility by fixing nitrogen and promoting soil microbes. Therefore, it is high time that we develop intercropping systems, especially with pulses as component crops in proper row ratios to meet the twin goals of profitability and sustainability. Also, on account of declining soil organic matter in rainfed condition, organic nutrient management practices would help in enhancing yields, income and soil health. Consequently, the current tendency is to investigate the feasibility of replacing chemical fertilizers with organic ones that are economic and environmentally friendly (Sarkar *et al*. 2021). Biofertilizer inoculation promotes crop growth by nitrogen fixation, solubilization of insoluble phosphate and synthesis of growth hormones, and siderophores. According to Ghosh *et al*. (2009), biofertilizers have demonstrated positive results in maintaining agricultural productivity and enhancing soil fertility. Utilising biofertilizers along with organic manures

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could prove to be a practical strategy for maintaining crop yield. In this regard, an experiment was conducted to study the influence of cropping systems and organic nutrient management practices on yield and economics of mustard + chickpea intercropping system.

MATERIALS AND METHODS

An experiment was conducted during the winter (*rabi)* seasons of 2021–22 and 2022–23 at the research farm of Indian Agricultural Research Institute farm, New Delhi (28°08' N and 77°12' E at an altitude of 228.61 m amsl). The soil of the experimental plot was sandy loam with *p*H 7.7 (slightly alkaline) and low in organic carbon (0.36%). It had medium available N (256 kg/ha), low available P (6.3 kg/ha) and medium available K (164 kg/ha). The experiment was conducted in split-plot design with cropping systems, viz. mustard sole; chickpea sole; mustard + chickpea 2:5; mustard + chickpea 5:2 as main plots and nutrient management practices, viz. control; 60 kg nitrogen/ha; 20 kg nitrogen through farmyard manure + leaf manure @4 t/ha; 20 kg nitrogen through farmyard manure + leaf manure @4 t/ha + microbial consortia as sub-plots with 3 replications. Mustard variety Pusa Tarak was sown using a seed rate of 5 kg/ha at 45 cm row spacing and for chickpea, Pusa 1103 variety sown by using with the seed rate of 80 kg/ha at 30 cm row spacing. Sowing was done during winter season on 21 October in 2021 and on 18 October in 2022. Mustard crop was applied with recommended dose of fertilizer @60-40-40 kg of N, P_2O_5 and K_2O/ha whereas chickpea crop was applied with recommended dose @20-60-40 kg of N, P_2O_5 and K_2O/ha. The intercropping system was done as per replacement series and rows of component crop were adjusted accordingly. Harvesting of crops was done in second fortnight of March during both the years when leaves were observed dried and falling off as a sign of senescence. Mustard was harvested one week earlier than chickpea. After threshing, seed yields were taken.

The data were subjected to analysis of variance (ANOVA) in split-plot design for various observations (Gomez and Gomez 1984). The results were presented at 5% level of significance (P=0.05) and critical difference (CD) values were calculated to compare the various treatment means. The other production potential parameters and intercropping indices were calculated as:

Mustard equivalent yield: Seed yield of chickpea was converted to mustard equivalent yield, based on the prevailing market prices of the commodities as:

$$\text{Mustard equivalent yield} = \frac{\text{Seed yield of chickpea (q/ha)} \times \text{Price of chickpea (₹/q)}}{\text{Price of mustard (₹/q)}}$$

Land equivalent ratio (LER): LER = Li + Lj = (Yij/Yii) + (Yji/Yjj)

where, Y is the yield per unit area; Yii and Yjj are sole crop yields of the component crops, i (mustard) and j (chickpea) and Yij and Yji are intercrop yields. The partial LER values Li and Lj, represent the ratios of the yields of crop i and j when grown as intercrops, relative to sole crops.

Relative crowding coefficient (RCC): RCC = Yield of a component crop of mixture/Yield of its sole crops

Aggressivity (A): The aggressivity shows the degree of dominance of one crop over other when sown together.

Aij = (Yij/Yii x Zij) – (Yji/Yjj x Zji)

where, Aij is aggressivity value for component crop; i and Zij and Zji are the proportion of the component crops.

The prices of the inputs used for cultivation were computed for determining the cost of cultivation which was given in rupees (₹) per hectare. Economic values of seed and straw yield were estimated based on the prevailing minimum support prices for mustard and chickpea announced by Government of India.

RESULTS AND DISCUSSION

Effect on growth parameters, seed and stover yield of mustard: Plant height of mustard showed a gradual increase with advancement of crop age. The highest plant height at maturity in both the years was recorded in mustard + chickpea 2:5 (159.9 cm) followed by mustard + chickpea 5:2 (156.7 cm) (Table 1). This might be due to more competition for light and space and nature of plant to grow vertically when they were in association with closer planting in mustard + chickpea intercropping system. The increase in the proportion of intercrops in the cropping system resulted in a greater interception of sunlight. This heightened exposure to light facilitated the rapid growth of the mustard plants through enhanced photosynthetic activities and the accumulation of dry matter during both the vegetative and reproductive stages. But intercropping systems had no significant influence on plant height at maturity. Among the nutrient management practices, maximum plant height (165.8 cm) was recorded in the plot treated with 20 kg N through FYM + leaf manure + microbial consortia. Plant height was more in 2022–23 than 2021–22 due to higher amount of effective rainfall received in the year. The optimum accumulation of dry matter followed by adequate partitioning of assimilates to developing sinks enables the crop to attain its true yield potential. Total dry matter accumulation at maturity was recorded the highest in mustard + chickpea 2:5 plot (227.5 g/m row length) followed by mustard + chickpea 5:2 cropping system. Among nutrient management practices, integrated application of organic manures providing adequate amounts of both macro and micronutrients, recorded significantly higher dry matter accumulation at maturity over other treatments during both the seasons. Considering individual mustard crop, seed yield and stover yield of mustard was recorded the highest in mustard sole (1.75 t/ha and 6.38 t/ha respectively) which was significantly higher over intercropping systems in both the years, presumably due to the absence of competition and higher plant population. Increase in population per unit area increases the vegetative growth and dry matter production which reflected in seed yield of mustard followed by mustard + chickpea 5:2 cropping system and chickpea sole crop. Taking the yield of both the crops together as a system, maximum yield was observed in mustard + chickpea 5:2 intercropping system. This might be due to increased availability of photosynthates which would have increased the number of flowers, and their fertilization resulted in higher number of siliquae/plants thus attaining higher yields. Similarly, maximum seed and stover yield of mustard was recorded in the plot supplied with mixture of farmyard manure, leaf manure and microbial consortia due to better nutrient uptake and higher dry matter accumulation. This is because organic manures ensure supply of all the macro and micro nutrients in right proportion to the plants for their enhanced growth and development. In addition to that, they help to increase the population of beneficial microbes which release organic acids and aid in fast decomposition, mineralization and solubilization processes of nutrients in the soil (Paramesh *et al*. 2020).

Effect on growth parameters, grain and straw yield of chickpea: Plant height showed a progressive trend from 30 days after sowing to harvest. Plant height at maturity of individual chickpea crop was recorded the highest in mustard + chickpea 2:5 plot (38.5 cm) (Table 1). This was owing to better utilization of resources especially solar radiation and temperature. Among the sub-plots, 20 kg N through farmyard manure + leaf manure + microbial consortia gave the highest plant height on account of better nutrient availability at right crop stage (40.7 cm). Similar trend was observed in dry matter accumulation too where maximum values were recorded in mustard + chickpea 2:5 intercropping system (156.9 g/m row length). This may be attributed to the plants being more photosynthetically efficient for higher assimilate and dry matter production leading to better vegetative growth. Considering individual chickpea plant, chickpea sole plot gave the maximum grain (1.99 t/ha) and straw yield (1.58 t/ha) due to better utilization of both above and below ground resources efficiently. This might be due to lesser inter-crop competition, higher photosynthetic active radiation and latent heat available to the crop leading to higher production of photosynthates which together favourably influenced the yield attributing parameters. The reduction in the grain and straw yield of chickpea under intercropping system was significantly higher than mustard which showed more competition and shading effect of tall mustard. Both grain yield (1.60 t/ha) and straw yield (1.22 t/ha) of chickpea was recorded to be the highest in 20 kg nitrogen through farmyard manure + leaf manure @4 t/ha + microbial consortia treatment. This may be on account of greater availability of both macro and micronutrients in suitable proportions through organic manures and further solubilization of nutrients by microbial consortia. Also, the symbiotic relationship between *Rhizobium* and chickpea root enhanced fixation of atmospheric nitrogen enabling better nutrient uptake and subsequently produced higher yields. Farmyard manure and leaf manure application helps to decrease nutrient losses by modifying the physical and chemical properties of soil (Bhattacharjee and Dey 2012). Organic manures have low C: N ratio which results in

Table 1 Effect of cropping system and nutrient management practices on growth parameters and yield of mustard and chickpea (mean data of years 2021–22 and 2022–23)

Treatment	Mustard				Chickpea			
	Plant height at maturity (cm)	Dry matter accumulation at maturity (g/m row length)	Seed yield (t/ha)	Stover yield (t/ha)	Plant height at maturity (cm)	Dry matter accumulation at maturity (g/m row length)	Grain yield (t/ha)	Straw yield (t/ha)
Cropping system								
Mustard sole	154.6	218.9	1.75	6.38	–	–	–	–
Chickpea sole	–	–	–	–	37.6	152.9	1.99	1.58
Mustard + Chickpea (2:5)	159.9	227.5	0.80	2.35	38.5	156.9	1.50	1.24
Mustard + Chickpea (5:2)	156.7	222.6	1.31	4.77	37.8	154.8	0.85	0.67
SEm±	2.70	4.00	0.09	0.23	0.67	2.69	0.04	0.05
CD (P=0.05)	NS	NS	0.29	0.68	NS	NS	0.15	0.16
Nutrient management practice								
Control	143.5	188.8	1.16	4.27	34.5	71.6	1.27	1.05
60 kg Nitrogen/ha	151.7	216.9	1.29	4.51	37.3	76.4	1.35	1.18
20 kg Nitrogen through FYM + leaf manure	161.3	238.8	1.31	4.58	40.4	80.5	1.56	1.21
20 kg Nitrogen through FYM + leaf manure + microbial consortia	165.8	245.5	1.38	4.66	40.7	81.7	1.60	1.22
SEm±	2.60	4.09	0.07	0.12	0.63	2.59	0.05	0.05
CD (P=0.05)	7.80	12.16	0.20	0.37	1.86	7.60	0.16	0.15

quicker decomposition rates thus supplying the plant with adequate amount of nutrients. Application of organic nutrient sources increase available N, P and K. It also increases soil organic carbon which enhances the soil fertility status. It improves soil structure and helps in release of secondary nutrients like calcium and magnesium into the soil solution.

Effect on mustard equivalent yield and intercropping indices: Yield of component crop i.e. chickpea was converted to yield of main crop i.e., mustard by taking mustard equivalent yield considering price of both the crops. Mustard equivalent yield was significantly influenced both by cropping systems and nutrient management practices. Mustard + chickpea 5:2 row ratio recorded the highest value of mustard equivalent yield (2.34 t/ha) followed by mustard sole crop, depicting advantage of intercropping (Fig 1). Five rows of mustard planted closely with two rows of chickpea utilize space, nutrients and solar radiation effectively thus producing higher biomass and yields. Intriguingly, it was observed that as the proportion of pulses such as chickpea increased in the intercropping system, there was a notable mutual benefit in terms of resource availability, particularly in the nitrogen economy and overall yield production for the mustard crop. Among the nutrient management practices, integrated application of farmyard manure, leaf manure and microbial consortia gave the highest mustard equivalent yield (2.94 t/ha) (Fig 2). The probable reason could be the secretion of growth promoting substances by microbial inoculants, which led to better root development, nutrient uptake and higher yields. Intercropping indices were calculated to determine the advantage of intercropping.

All the intercropping systems had land equivalent ratio more than unity, depicting intercropping advantage. Land equivalent ratio was determined and mustard + chickpea 5:2 row ratio with integrated application of organic manures and microbial consortia gave the highest value of 1.54 (Table 2). It was followed by mustard + chickpea 2:5 cropping system (1.34). The aggressivity values of mustard was positive in all cropping systems thus indicating its dominance over chickpea. Aggressivity values of intercropping were higher than zero, indicating yield advantage of intercropping over sole cropping. All the intercropping treatments had higher relative crowding coefficient values, and the product of relative crowding coefficients exceeded unity, indicating their yield advantage compared with their monocultures due to the complementary relationship. The highest relative crowding coefficient value of system (7.25) in mustard + chickpea 5:2 row ratio indicated that the system in this row proportion gave more yield than expected. Among nutrient management practices, integrated application of 20 kg N through farmyard manure, leaf manure and microbial consortia gave the highest values of all intercropping indices. It recorded the highest LER (1.56) and relative crowding coefficient of system (13.62) among the nutrient-management practices (Table 2). The lower competition was observed under control plot and plot fertilized with 60 kg N/ha through chemical fertilizer. The observed increase in fertility levels by application of organic manures could have played a role in promoting greater vegetative growth and the development of an extensive root system capable enough to extract moisture from deeper layers of soil subsequently leading to higher yields. Lal *et al.* (2019) also reported similar results with respect to aggressivity and relative crowding co-efficient values in linseed + gram intercropping system. Thus, the

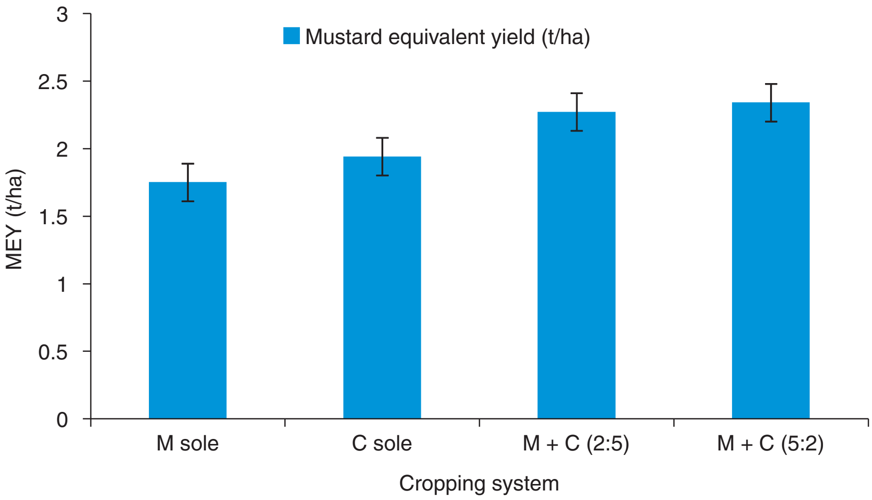

Fig 1 Effect of cropping system on mustard equivalent yield of system (mean data of years 2021–22 and 2022–23).

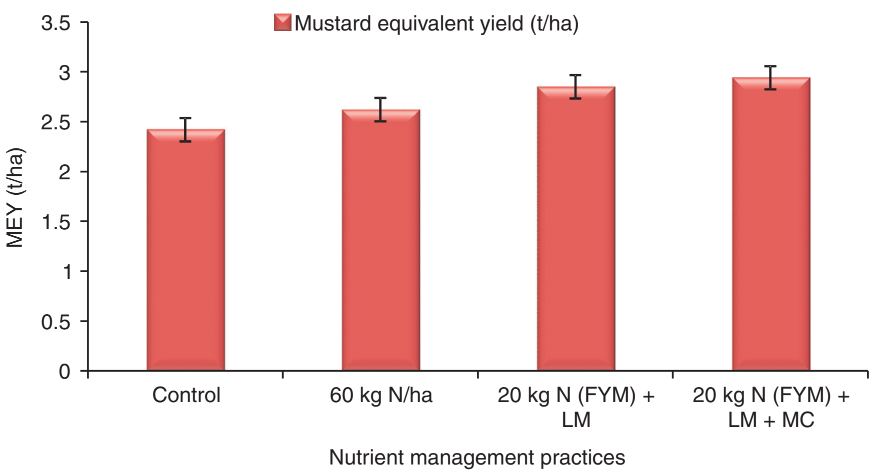

Fig 2 Effect of nutrient management practices on mustard equivalent yield of system (mean data of years 2021–22 and 2022–23).

Table 2 Effect of cropping system and nutrient management practices on intercropping indices of system (mean data of years 2021–22 and 2022–23)

Treatment	Land equivalent ratio	Aggressivity of mustard	Aggressivity of chickpea	Relative crowding coefficient of system
Cropping system				
Mustard + Chickpea (2:5)	1.34	0.18	(-) 0.18	5.74
Mustard + Chickpea (5:2)	1.54	0.28	(-) 0.28	7.25
Nutrient management practice				
Control	1.37	0.33	(-) 0.33	2.03
60 kg Nitrogen/ha	1.39	0.24	(-) 0.24	4.63
20 kg Nitrogen through FYM + leaf manure	1.45	0.20	(-) 0.20	8.30
20 kg Nitrogen through FYM + leaf manure + microbial consortia	1.56	0.15	(-) 0.15	13.62

results clearly showed intercropping of mustard + chickpea in 5:2 row ratio along with application of organic manures is the best option to achieve potential yields and income under rainfed condition.

Economics as influenced by intercropping systems and nutrient management practices: The inspection of data indicated that the imposed treatments produced marked variation in economic parameters (Table 3). Cost of cultivation was not significantly influenced by cropping systems but was significantly influenced by nutrient management practices. Maximum cost of cultivation was incurred for the plot mustard + chickpea 2:5 row ratio (₹30,610) taking into consideration both seed rate and seed cost. Also, organically treated plots incurred more cost (₹32,670) as it had to be applied in bulk amounts due to low nutrient concentration in them. Gross returns and net returns were calculated considering both rate of produce and minimum support price even though, mustard + chickpea 5:2 intercropping system recorded highest cost of cultivation, yet it provided for highest gross returns (₹84,560), net returns (₹54,040) and B:C ratio (1.77) as compared to sole cropping system for both the years due to higher yields. It was followed by mustard sole crop and mustard + chickpea 2:5 cropping system. Similar results were also reported by Singh *et al.* (2019). Among nutrient management practices, maximum gross returns, net returns along with B:C was observed for the treatment where the plot was subjected to integrated application of farmyard manure, leaf manure and microbial consortia. This was on account of higher yields attained on application of organic nutrient sources than inorganic chemical fertilizers.

Thus, as per the findings of experimental research, it was well established that yield of cropping system as a whole in terms of mustard equivalent yield based on price of produce was recorded the highest in mustard + chickpea (5:2) intercropping system. Gross returns, net

Table 3 Effect of cropping system and nutrient management practices on economics of system (mean data of years 2021–22 and 2022–23)

Treatment	Cost of cultivation (₹ × 10^3/ha)	Gross returns (₹ × 10^3/ha)	Net returns (₹ × 10^3/ha)	Net B:C
Cropping system				
Mustard sole	30.11	81.90	51.78	1.72
Chickpea sole	30.28	55.72	25.44	0.84
Mustard + Chickpea (2:5)	30.61	79.24	48.63	1.59
Mustard + Chickpea (5:2)	30.51	84.56	54.04	1.77
SEm±	0.56	1.14	0.92	0.02
CD (P=0.05)	NS	3.38	2.73	0.07
Nutrient management practice				
Control	28.49	89.60	61.10	2.14
60 kg Nitrogen/ha	29.17	97.86	68.69	2.33
20 kg Nitrogen through FYM + leaf manure	32.36	104.10	71.79	2.21
20 kg Nitrogen through FYM + leaf manure + microbial consortia	32.67	108.70	76.10	2.35
SEm±	0.62	1.37	1.29	0.03
CD (P=0.05)	1.86	4.09	3.82	0.10

returns, net B:C was also found the highest in this treatment. Among the nutrient management practices, both mustard equivalent yield and economic parameters were recorded the highest with integrated application of organic manures and microbial consortia (20 kg N through FYM+ Leaf manure+ Microbial consortia). Values of intercropping indices like land equivalent ratio, aggressivity and relative crowding coefficient revealed advantage of mustard + chickpea 5:2 intercropping system over sole cropping system. Thus, adoption of mustard + chickpea 5:2 row ratio along with integrated application of organic nutrient sources like farmyard manure, leaf manure and microbial consortia has the potential to generate higher yields and income for the farmers under rainfed condition.

REFERENCES

Bhattacharjee R and Dey U. 2012. Biofertilizer, a way towards organic agriculture: A review. *African Journal of Microbiology Research* **8**(24): 2332–43.

Ghosh P K, Tripathi A K, Bandyopadhyay K K and Manna M C. 2009. Assessment of nutrient competition and nutrient requirement in soybean/sorghum intercropping system. *European Journal of Agronomy* **31**(1): 43–50.

Gomez K A and Gomez A A. 1984. *Statistical Producers for Agricultural Research*, 2nd edn, Vol. 1, pp. 372–81. John Wiley and Sons Incorporation press, New York.

Lal B, Rana K S, Rana D S, Shivay Y S, Sharma D K, Meena B P and Gautam P. 2019. Biomass, yield, quality and moisture use of *Brassica carinata* as influenced by intercropping with chickpea under semiarid tropics. *Journal of the Saudi Society of Agricultural Sciences* **18**(1): 61–71.

Mucheru-Muna M, Pypers P, Mugendi D, Kung'u J, Mugwe J, Merckx R and Vanlauwe B. 2010. A staggered maize legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. *Field Crops Research* **115**(3): 132–39.

Paramesh V, Sreekanth G B, Chakurkar E, Chethan Kumar H, Gokuldas P and Manohara K K. 2020. Ecosystem network analysis in a smallholder integrated crop–livestock system for coastal lowland situation in tropical humid conditions of India. *Sustainability* **12**(3): 5017–48.

Ramarao, Chandranath H T, Babalad H B and Hegde Y. 2020. Growth, yield and oil quality of mustard in chickpea (*Cicer arietinum*) and mustard (*Brassica juncea*) intercropping system under different row ratio in northern transition zone of Karnataka. *Indian Journal of Agricultural Research* **10**(1): 1–7.

Sarkar D, Rakshit A, Al-Turki A I, Sayyed R Z and Datta R. 2021. Connecting bio-priming approach with integrated nutrient management for improved nutrient use efficiency in crop species. *Agriculture* **11**(4): 372–76.

Singh V, Singh G, Pandey V K, Kumar M and Singh A. 2019. Performance of chickpea-mustard intercropping on yield and economics of chickpea and mustard crop under different fertility management and various row combinations. *International Journal of Current Microbiology and Applied Sciences* **8**(1): 236–49.

Viswanathan P K, Kavya K and Bahinipati C S. 2020. Global patterns of climate-resilient agriculture: A review of studies and imperatives for empirical research in India. *Review of Development and Change* **25**(2): 169–92.

Willey R W. 1990. Resource use in intercropping systems. *Agricultural Water Management* **17**(3): 215–23.