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Assessment of intercropping indices of mustard (*Brassica juncea* L.) with chickpea and field pea ratio

MH Chavda, KM Patel, YB Vala, MG Chaudhary and JS Desai

Abstract
A field experiment was carried out during the winter (*rabi*) of 2019-20 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar to study the effect of intercropping in mustard (*Brassica juncea* L.) nine treatment combination *viz.,* T_1: Sole mustard, T_2: Sole chickpea, T_3: Sole field pea, T_4: Mustard + chickpea (1:2), T_5: Mustard + chickpea (1:3), T_6: Mustard + chickpea (1:4), T_7: Mustard + field pea (1:2), T_8: Mustard + field pea (1:3) and T_9: Mustard + field pea (1:4) were laid out in randomized block design replicated 3 times. Among different intercropping systems, mustard + field pea (1:4) recorded maximum aggressively, crowding coefficient and competitive ratio in mustard. While, Area time efficiency ratio, production efficiency, system profitability, value: cost ratio and relative value total maximum observed in Mustard + chick pea (1:3) ratio.

Keywords: Mustard, chickpea, field pea and intercropping

Introduction

Mixed cropping is an age-old practice among, the traditional system of Indian agriculture. Concentrating on the need to increase the crop production, intercropping offers a great promise in the modern agriculture, where compatible crop combination is grown simultaneously on a unit piece of land by using high inputs. The main advantage of intercropping is the increase in productivity by exploiting the full duration of solar radiation, thermal energy, water and nutrient resources in resource limited ecosystem. Moreover, intercropping can maintain or enhance soil quality, promote biodiversity, control weed growth, minimize the incidence of pest and diseases, reduce soil erosion and runoff discharge, and increase farming incomes.

The crop compatibility is the most essential factor in a feasible intercropping system. The success of any intercropping system depends on the proper selection of crop species where competition between them for light, space, moisture and nutrients is minimized (Fukai & Trenbath, 1993) [15]. On the other hand, selection of proper crop species in an intercropping could enhance the scope of increasing overall production per unit of land and time. Yield advantage occurs as growth resources such as light, water, and nutrients required by the intercrops vary over time and space as a result of differences in competitive ability for growth resources between the crops in characteristics such as rates of canopy development, final canopy size, photosynthetic adaptation of canopies to irradiance conditions and rooting depth (Midmore, 1993) [9]. Normally, complementary use of resources occurs when the component species of an intercrop use quantitatively different resources or they use the same resources at different places or at different times.

Intercropping is recommended to be used in many parts of the world for food or fibres productions, because of its overall high productivity, effective control of pests and diseases, good ecological services and economic profitability. In an intercropping system, there are often two or more crop species grown in the same field for a certain period of time, even though the crops are not necessarily sown or harvested simultaneously. In practice, most intercropping systems involve only two crops, as inclusion of more crops results in higher labour costs. Mostly, intercropping is practiced with the aim of maximum plant competition rather than plant competition for maximum crop yield. The success of intercropping systems is due to an enhanced temporal and spatial complementarity of resource capture, for which both above-ground and belowground parts of crops play an important role. Even though two crops compete for soil N as they both need it for the growth, the competition drives legumes to fix atmospheric N_2 in symbiosis with *Rhizobium*. This actually results in complementary utilization of N by the crops, which is of particular importance in soils where inorganic N is limited or over-fertilized. However, negative intercropping productivity due to interspecific competition has also been reported, especially when the fields are managed inappropriate. Therefore, only reasonable use of competitive and facilitative interactions between crops in intercropping systems can enhance crop productivity.

Material and Methods

A field experiment was conducted at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *rabi* season of the year 2019-20. The soil of the experimental field was loamy sand in texture. The present experiment comprising of nine treatments combinations *viz.*, T_1: Sole mustard, T_2: Sole chickpea, T_3: Sole field pea, T_4: Mustard + chickpea (1:2), T_5: Mustard + chickpea (1:3), T_6: Mustard + chickpea (1:4), T_7: Mustard + field pea (1:2), T_8: Mustard + field pea (1:3) and T_9: Mustard + field pea (1:4).In the present investigation mustard (Gujarat Mustard 1) was grown with chickpea (Gujarat Gram 3) and field pea (Dantiwada Field Pea 1) in different intercropping proportions on row basis of 1:2, 1:3 and 1:4. This was a replacement series of intercropping system, The main/base crop (mustard) and two intercrops (chickpea and field pea) were planted at 30 × 10 cm spacing. Crops were raised with their recommended package of practices. Total nine treatment combinations were tested in Randomized Block Design (RBD) with three replications. Economics was worked out on the basis of prevailing market prices of inputs and output obtained from each treatment. To evaluate the intercropping, indices such as, aggressivity**,** crowding coefficient (K), competitive ratio (CR), area time equivalency ratio (ATER), production efficiency (kg/day), system profitability (SP), value: cost ratio (VCR) and relative value total (RVT) were used.

1) Aggressivity

It gives a simple measure of how much relative yield increase in species 'a' is greater than that for species 'b' in an intercropping system (McGilchrist 1965) [8]. It measures the intercrop competition by relating the yield changes of both component crops.

$$\text{Aab} = \frac{\text{Yab}}{(\text{Yaa} \times \text{Zab})} - \frac{\text{Yba}}{(\text{Ybb} \times \text{Zba})}$$

Where:
Aab = Zero mean component crops are equally competitive
Aab = negative means dominated
Aab = Bigger value either positive or negative means bigger difference in competitive abilities.

2) Crowding coefficient (K)

De Wit (1960) [5] introduced the relative crowding coefficient (RCC or K) in plant competition theory. Crowding effect is also one of the indices used in computing the competition effect of intercropping. It gives a measure of the relative dominance of one species over the other in multiple cropping (Banik *et al*., 2006) [3]. Each of the species within an intercropping has its own relative crowding coefficient and the one with higher values are said to be more dominant. It was calculated according to the formula below;

$$\text{Kab} = \frac{\text{Yab}}{\text{Yaa} - \text{Yab}} \text{ and } \text{Kba} = \frac{\text{Yba}}{\text{Ybb} - \text{Yba}}$$

Where:
Kab and Kba are the relative crowding coefficient of wheat in legume and legume in maize respectively; Yaa and Ybb are yields of maize and legumes in monoculture; Yab is the yield of maize in poly culture with a legume and Yba to denote the yield of the legume in the intercrop. When the value of K is greater than 1, there is a yield advantage, when K is equal to 1, it indicates no yield advantage and K values less than one show a yield disadvantage of intercropping.

3) Competitive ratio (CR)

Competitive Ratio (CR) was proposed by Willey and Rao (1980) [13]. They suggested that instead of taking the difference of two terms of aggressivity, take the ratio of these terms which they designed as Competitive Ratio (CR). It is a measure of intercrop competition to indicate the number of times by which the component crop is more competitive than the other.

$$\text{CR} = \frac{\text{Yab}}{\text{Yaa} \times \text{Zab}} \div \frac{\text{Yba}}{\text{Ybb} \times \text{Zba}}$$

Where:
Yab= mixture yield of a crop grown with b,
Yba= mixture yield of b crop grown with a,
Yaa= yield in pure stand of crop a,
Ybb= yield in pure stand of crop b.

4) Area time equivalency ratio (ATER)

It is the ratio of number of hectare-days required in monoculture to the number of hectare-days used in intercropping to produce identical quantities of each of the component crop. ATER provides more realistic comparison of the yield advantage of intercropping over monocropping in terms of time taken by component crops in the intercropping systems (Hiebsch & McCollum 1987; Aasim *et al*. 2008; Yahuza 2011) [6, 1, 14]. ATER was calculated using the following formula:

$$\text{ATER} = \frac{[(\text{RYa} \times \text{ta}) + (\text{RYb} \times \text{tb})]}{\text{T}}$$

Where,

$$\text{RYa} = \frac{\text{Yield of intercrop a}}{\text{Yield of monocrop a}} \text{ And } \text{RYb} = \frac{\text{Yield of intercrop b}}{\text{Yield of monocrop b}}$$

Where:
ta= Duration of species a (days)
tb= Duration of species b (days)
T= Duration of intercropping (days)

5) Production efficiency (kg/day)

Production efficiency (PE) is worked out as given below to find out the economics of individual intercropping system.

$$\text{PE} = \frac{\text{Equivalent yield (kg)}}{\text{Duration (days)}}$$

6) System profitability (SP)

This gives the efficiency of the cropping system in terms of monetary value, also the land use efficiency if the above formula denominator is replaced with 365, if the yield could be completed within a year.

$$SP = \frac{\text{Net return}}{\text{Duration of intercropping}}$$

7) Value: cost ratio (VCR)

These indices provide an estimate of the benefit a farmer derives for the expenditure incurred in adopting a particular cropping system. Similarly, return on investment on labour, chemical etc., can be computed to evaluate the system through various angles.

$$VCR = BCR - 1$$

8) Relative value total (RVT)

$$RYT = \frac{(aP1 + bP2)}{aM1}$$

In this equation, a is the price of the main crop, b the price of the secondary crop, P1 the yield of the main crop of intercropping, P2 the yield of the secondary crop of intercropping, M1 the yield of the pure cropping of the main species. If RVT is bigger than 1, the intercropping is economically preferable; whereas if RVT is smaller than 1, the pure cropping is preferable. Provided that RVT is equal to 1, neither of the methods is economically superior to the other.

Result and Discussion

The data regarding intercropping indices of mustard with chickpea and field pea are presented in Table 2 and 3. The data were not analysed statistically hence, the inferences were drawn from the mean values.

Aggressivity

As regards to aggressivity index it was observed that aggressivity index was maximum in T_9 *i.e.* mustard + field pea 1:3 ratio in case of mustard over all the treatment combinations. This dominance was more pronounced in the mustard association with the field pea then chickpea. Aggressivity index of intercrop was negative indicating the dominance of mustard in the intercropping system. Similar types of findings were also reported by Ahlawat *et al*. (2005) [2] and Choudhuri and Jana (2015) [4].

Relative crowding coefficient (K)

Relative crowding coefficient was worked out for different intercropping treatments are presented in Table 1. Relative crowding coefficient for mustard crop was recorded maximum at 1:4 proportion of mustard + chickpea. Mustard in combination with chickpea recorded maximum RCC indicating its more yield advantage than field pea.

Competitive ratio

The competitive ratio of mustard with intercrops recorded due to different treatment combination indicated that higher competitive ratio of mustard was greater than intercrops. This highest value of competitive ratio of mustard indicated its superior ability of competition than that of chickpea/field pea. This Competition was more pronounced in the mustard association with the field pea then chickpea. Higher the competitive ratio, higher will be the competitive ability of crop with its companion crop. Choudhuri and Jana (2015) [4] and Jakhar *et al*. (2015) [7] reported similar type of findings.

Area time efficiency ratio

Under all intercropping treatments, ATER was more than one expect mustard with field pea intercropping. Mustard + chickpea 1:3 ratio recorded the highest ATER than all other intercropping treatments. In different planting patterns, 1:3 ratio recorded more ALER followed by 1:4 and 1:2 ratios.

Production efficiency, system profitability and value: cost ratio

Under almost all intercropping treatments, production efficiency, system profitability and value: cost ratio were recorded under mustard + chickpea in 1:3 ratio. However, it was closed followed by mustard + chickpea 1:4 ratio. This was due to higher production of chickpea compare to field pea because of that coupled with better utilization of resources of the component crop in intercropping system. It was also noticed that in all the intercropping systems these parameters showed increasing trend with increasing proportion of intercrop in intercropping system. This may be attributed to better utilization of resources and their ultimate reflection in the economic parameters due to greater mutual benefit of legumes with the increasing proportion in the intercropping system. Similar types of results have been reported by Sawant (1989) [11] in case of oilseed + pulse intercropping.

Relative value total

The data regarding relative value total of mustard and intercrops as affected by various treatments are presented in Table 2. The problem with LER is that such calculation does not account for the value of the crops that are being sown. The solution to this problem is provided in calculating relative value total (RVT) of the crop mixtures. Such calculation is relevant for the farmer that has monetary value as his farming goal (Vandermeer, 2004) [12]. The relative value total of mustard recorded under 1:3 and 1:4 ratio of mustard + chickpea system was higher than all remaining intercropping treatments. This subject indicates the economical advantage of mustard and chickpea intercropping more than the sole cropping of mustard. One reason for the preference of the intercropping over the pure cropping, is the lesser interspecific competition of the crops of intercropping compared to the intraspecific competition of the crops of pure cropping. Similar results were also reported by Rahimi *et al*. (2011) [10]. The results showed that the relative value total of field pea in all intercropping treatments was lower than sole cropping of field pea.

Table 1: Seed and stover/straw yield (kg/ha) of cropping system

Treatments			Seed yield (kg/ha)		Stover/ straw yield (kg/ha)	
			Mustard	Intercrop	Mustard	Intercrop
T_1	:	Sole mustard	2103	-	4615	-
T_2	:	Sole chickpea	-	1729	-	1895
T_3	:	Sole field pea	-	728	-	968
T_4	:	Mustard + chickpea (1:2)	1069	1168	2347	1282
T_5	:	Mustard + chickpea (1:3)	840	1431	1829	1584
T_6	:	Mustard + chickpea (1:4)	819	1439	1788	1587
T_7	:	Mustard + field pea (1:2)	999	301	2189	429
T_8	:	Mustard + field pea (1:3)	807	398	1775	554
T_9	:	Mustard + field pea (1:4)	760	419	1677	565
Sell price: Mustard seed: ₹ 50.00/kg Chickpea seed: ₹ 60.00/kg Field pea seed: ₹ 90.00/kg Stover/straw: ₹ 1.00/kg				Days in field: Mustard crop: 118 Chickpea/field pea crop: 117		

Table 2: Aggressivity, crowding coefficient (K) and competitive ratio of the cropping system

Treatments			Aggressivity		crowding coefficient (K)			Competitive ratio	
			Mustard	Intercrop	Mustard	Intercrop	System CC	Mustard	Intercrop
T_1	:	Sole mustard	-	-	-	-	-	1	-
T_2	:	Sole chickpea	-	-	-	-	-	-	1
T_3	:	Sole field pea	-	-	-	-	-	-	1
T_4	:	Mustard + chickpea (1:2)	0.54	-0.54	2.18	1.04	3.22	2.44	0.45
T_5	:	Mustard + chickpea (1:3)	0.49	-0.49	2.03	3.36	5.39	2.45	0.53
T_6	:	Mustard + chickpea (1:4)	0.91	-0.91	2.55	2.00	4.55	3.65	0.29
T_7	:	Mustard + field pea (1:2)	0.83	-0.83	2.01	0.35	2.36	5.81	0.21
T_8	:	Mustard + field pea (1:3)	0.45	-0.45	1.93	0.42	2.35	4.98	0.25
T_9	:	Mustard + field pea (1:4)	1.09	-1.09	2.34	0.35	2.69	6.79	0.19

Table 3: Area time efficiency ratio (ATER), production efficiency (kg/day), system profitability (₹/day), value: cost ratio and relative value total of cropping system

Treatments			Area time efficiency ratio (ATER)	Production efficiency (kg/day)	System profitability (₹/day)	Value: Cost ratio	Relative value total
T_1	:	Sole mustard	678	2.60	678	2.60	-
T_2	:	Sole chickpea	1.00	18.06	626	2.26	-
T_3	:	Sole field pea	1.00	11.37	296	1.09	-
T_4	:	Mustard + chickpea (1:2)	1.18	21.74	815	3.00	1.18
T_5	:	Mustard + chickpea (1:3)	1.23	22.43	849	3.11	1.21
T_6	:	Mustard + chickpea (1:4)	1.21	22.34	843	3.07	1.21
T_7	:	Mustard + field pea (1:2)	0.89	13.62	412	1.53	0.74
T_8	:	Mustard + field pea (1:3)	0.93	13.42	402	1.49	0.73
T_9	:	Mustard + field pea (1:4)	0.94	13.32	396	1.47	0.72

Conclusion

As per one year experiment, amongst different intercropping systems, mustard + field pea (1:4) recorded ceiling aggressively, crowding coefficient and competitive ratio in mustard. whereas, Area time efficiency ratio, production efficiency, system profitability, value: cost ratio and relative value total maximum received under Mustard + chick pea (1:3) ratio.

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