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EVALUATION OF INTERCROPPING INDICES IN MUSTARD-BASED VEGETABLE INTERCROPPING SYSTEMS

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ABSTRACT

The study was conducted at Agricultural Research Station, Adilabad, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad, from November, 2022 to March, 2023 to identify the best intercropping system in mustard intercropped with different root vegetable crops. The treatments include, T_1: Mustard sole crop; T_2: Radish sole crop; T_3: Beetroot sole crop; T_4: Carrot sole crop; T_5: Potato sole crop; T_6: Mustard + Radish (2:2); T_7: Mustard + Beetroot (2:2); T_8: Mustard + Carrot (2:2); T_9: Mustard + Potato (2:2); T_{10}: Mustard + Radish (3:3); T_{11}: Mustard + Beetroot (3:3) ; T_{12}: Mustard + Carrot (3:3); T_{13}: Mustard + Potato (3:3). Results indicated that, mustard sole crop performed significantly better in terms of growth and yield parameters. However, among the intercropping systems, Land equivalent ratio and land use efficiency was found to be higher in mustard + radish (1.14 and 159.6 %) with 3:3 row proportion, respectively. In different intercropping system highest Relative Crowding Coefficient (RCC) and aggressivity was recorded in mustard + radish in 3:3 (1.79 and (0.213). While the highest ATER was recorded in mustard + beetroot/ carrot 3:3 (0.99) compared to all the intercropping systems. The study concludes that, mustard + radish in both 3:3 and 2:2 row proportions can be a better intercropping system for Telangana.

***Keywords* :** Equivalent yield**,** Land equivalent ratio, Relative crowding coefficient, Land use efficiency.

Introduction

Mustard (*Brassica juncea* L.) is one of the most important oilseed crops cultivated during the rabi season under both irrigated and rainfed conditions in India. It plays a vital role in meeting the edible oil demand of the country, which continues to exceed domestic production. India ranks second in area and third in production of rapeseed-mustard, occupying about 6.8–7.0 million hectares with a production of over 9 million tonnes (Anonymous, 2022). In the face of rapid population growth, increasing food and nutritional security concerns and shrinking natural resources, there is an urgent need to enhance productivity per unit area and per unit time (Singh and Bohra, 2012; Kushwaha and De, 2009; Tripathy *et al.*, 2023; Singh *et al.*, 2018). Since there is limited scope for horizontal expansion of cultivable land, vertical intensification through efficient cropping systems is essential (Tilman *et al.*, 2011; Godfray *et al.*, 2010).

In northern Telangana, mustard cultivation has gained importance in recent years due to its adaptability to residual soil moisture, low input requirement and suitability to smallholder farming systems. However, productivity levels remain low compared to potential yields, mainly due to poor resource use efficiency and dominance of monocropping systems. Intercropping, in particular, is an effective strategy that enhances system productivity, stabilizes yield, reduces production risks and improves soil health (Lithourgidis *et al.*, 2011; Brooker *et al.*, 2015). Mustard-based intercropping systems have shown promising results in improving productivity and profitability under different agro-ecological conditions (Singh *et al.*, 2017; Kumar *et al.*, 2018; Yadav and Kumar, 2019). The inclusion of root vegetable crops offers additional advantages due to their short duration, high market value and distinct morphological characteristics (Meena *et al*., 2015; Kour *et al*., 2013). Furthermore, these vegetables contribute significantly to nutritional security by supplying essential vitamins and minerals. The success of such systems largely depends on appropriate crop combinations and spatial arrangements, as row ratios influence plant population, competition and complementarity among component crops (Devi *et al*., 2014; Singh and Rana, 2016). However, limited research has been carried out on mustard–root vegetable intercropping systems under the specific agro-climatic conditions of northern Telangana.

Materials and Methods

A field experiment was conducted at Agricultural Research Station, Adilabad, Telangana during *rabi*, 2022 in black soil with neutral pH (7.35), having EC of 0.19 dS m^{-1}, medium in organic carbon (0.67%) and low in available nitrogen (100.8 kg ha^{-1}), medium in phosphorus (47.4 kg ha^{-1}) and high in potassium (426 kg ha^{-1}). The experiment was laid out in randomized block design with 13 treatments and 3 replications.

Table 1: Treatment details

Treatment	Details
T1	Sole mustard
T2	Sole radish
T3	Sole beetroot
T4	Sole carrot
T5	Sole potato
T6	Mustard + radish (2:2)
T7	Mustard + beetroot (2:2)
T8	Mustard + carrot (2:2)
T9	Mustard +potato (2:2)
T10	Mustard + radish (3:3)
T11	Mustard + beetroot (3:3)
T12	Mustard + carrot (3:3)
T13	Mustard +potato (3:3)

Intercropping indices:

Mustard equivalent yield

MEY was calculated as below,

$$\text{MEY (Crop a)} = \frac{\text{Yield (crop a) x Price (a)}}{\text{Price of base crop}}$$

Where,

Yield (a) is the yield of individual crop (a) in kg harvest product ha^{-1},

Price (a) is the price of crop (a) and market price of base crop.

Land use efficiency

Both area and time factors have to be considered to quantify land-use efficiency if the yield of mustard crop, is to be compared with intercrops, such as carrot, beetroot, radish and potato. Thus, the overall efficiency of each intercropping system was assessed using both the land-equivalent-ratio (LER) and the Area time-equivalent-ratio (ATER).

$$\text{LUE (\%)} = \text{LER} + \left(\frac{\text{ATER}}{2}\right)$$

Land equivalent ratio

The index commonly used to evaluate the relative advantage of intercropping compared with sole crop is the total land equivalent ratio, *i.e.*, the relative land area required by sole crops to produce the yields achieved in intercropping (Willey and Rao, 1980), which was calculated as,

$$\text{Land Equivalent Ratio} = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where,

Y_{ab} is Yield of crop ‘a’ in intercropping

Y_{ba} is Yield of crop ‘b’ in intercropping

Y_{aa} is Yield of crop ‘a’ in pure stand

Y_{bb} is Yield of crop ‘b’ in pure stand

Relative crowding coefficient

De Wit (1960) proposes it to use in replacement series of intercropping. It indicates whether a species or crop when grown in mixed population has produced more or less yield than expected in pure stand. In 50:50 mixtures relative crowding coefficient can be calculated as,

$$K_{ab} = \frac{\text{Mixture yield of a}}{\text{Pure yield of a} - \text{mixture yield of a}} = \frac{Y_{ab}}{Y_{aa} - Y_{ab}}$$

But when population differ from 50: 50 then,

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

Where,

K is coefficient of each crop species

Y_{aa} is Yield of pure stand of “a”

Y_{bb} is Yield of pure stand of “b”

Y_{ab} is Mixture yield of a in combination with b

Y_{ba} is Mixture yield of b in combination with a

Z_{ab} is sown proportion of a in mixture with b

Z_{ba} is sown proportion of b in mixture with a

K_{ab} is values indicate the following conclusions:

Aggressivity

Aggressivity is proposed by Mc Gihrist (1965). It gives a simple measure of how much the relative yield increase in species A is greater than that for species B. It is an index of dominance.

$$A_{ab} = \frac{\text{mixture yield of a}}{\text{Expected yield of a}} - \frac{\text{mixture yield of b}}{\text{Expected yield of b}}$$

Where,

A_{ab} is aggressivity of a in intercropping system of a+b

If A_{ab} is zero, a and b crops are equally competitive,

A_{ab} is negative then a is dominated.

A_{ab} is positive then a is dominant.

Area time equivalent ratio (ATER)

ATER is defined as area needed by sole cropping to produce same yield as produce by intercropping system along with consideration of duration of crops. ATER was calculated as follows,

$$ATER = \frac{(L_a \times D_a) - (L_b \times D_b)}{T}$$

Where,

L_a and L_b are relative yields or partial LER of component crops a and b, respectively.

Da and Db are duration of crops a and b, respectively and

T is total duration of the intercropping system.

The ATER provides more realistic comparison of the yield advantage of intercropping over sole cropping than LER as it considers variation in time taken by the component crops of different intercropping systems.

Results and Discussion

Mustard equivalent yield

Data pertaining to mustard equivalent yield is shown in Table-2. There was a significant influence of intercropping mustard with different root vegetables on mustard equivalent yield. Among all treatments, significantly higher mustard equivalent yield was recorded in radish sole crop (5775 kg ha^{-1}) followed by potato, carrot and beetroot sole crops. Among the different intercropping systems, mustard + radish in 3:3 (3964 kg ha^{-1}) showed higher MEY, which was on par with mustard + radish in 2:2 (3933 kg ha^{-1}) and lower MEY was recorded in mustard + potato in 2:2 (2646 kg ha^{-1}).

Higher MEY in radish sole crop attributed to higher root yield compared to carrot, beetroot and potato crops. In mustard-based intercropping the mustard yield and extra yield of intercrops assisted in increasing mustard equivalent yield. Similar results were found in Wartha *et. al.* (2020), Naik *et. al.* (2020).

Table 2: Mustard equivalent yield as influenced by intercropping mustard with root vegetables

Treatments	Mustard equivalent yield (kg ha^{-1})
T_1 -Mustard sole crop	1556
T_2 -Radish sole crop	5775
T_3 -Beetroot sole crop	4482
T_4 - Carrot sole crop	4893
T_5 - Potato sole crop	3937
T_6 - Mustard + Radish (2:2)	3933
T_7 - Mustard + Beetroot (2:2)	3200
T_8- Mustard + Carrot (2:2)	3386
T_9- Mustard + Potato (2:2)	2646
T_{10} - Mustard + Radish (3:3)	3964
T_{11} - Mustard + Beetroot (3:3)	3218
T_{12} - Mustard + Carrot (3:3)	3406
T_{13} - Mustard + Potato (3:3)	2729
SEm ±	161.3
CD (P=0.05)	475.9

Land use efficiency (%) (LUE)

In different intercropping systems, mustard + radish (3:3) recorded highest land use efficiency (159.6%) and the lowest was recorded in mustard + potato 2:2 (142%). Remaining treatments were statistically on par with each other ($T_{10}>T_6>T_{12}>T_8>T_{11}>T_7>T_{13}>T_9$). Highest land use efficiency in mustard + radish 3:3 might be due to radish being a short duration crop. LUE greater than 100 in all treatments implies yield advantage in intercropping systems than sole crops.

Land equivalent ratio (LER)

LER values were observed to be higher than unity which signified yield advantages of intercropping over sole cropping (Table -3). Higher LER was found in mustard + radish 3:3 (1.14) and it was on par with mustard + radish (2:2) and mustard + carrot 2:2, whereas lower was recorded in mustard + potato 2:2 (0.96). In all intercropping systems LER values were greater than one signifying yield benefits from intercropping systems over the sole crops. The temporal and spatial complementarities were the key to get yield advantage. Similar observations were also made by several workers (Mahmoudi *et. al.*, 2013; Tohura *et. al.*, 2014, Pour *et. al.*, 2015 and Bechem *et. al.*, 2018).

Table 3: LER, ATER, LUE (%) as influenced by mustard intercropping with root vegetables

Treatments	LER	ATER	LUE
T_6 - Mustard + Radish (2:2)	1.13	0.89	157.3
T_7 - Mustard + Beetroot (2:2)	1.03	0.98	152.3
T_8 - Mustard + Carrot (2:2)	1.06	0.98	155.1
T_9 - Mustard + Potato (2:2)	0.96	0.92	142.3

T_{10} - Mustard + Radish (3:3)	1.14	0.91	159.6
T_{11} - Mustard + Beetroot (3:3)	1.04	0.99	153.5
T_{12} - Mustard + Carrot (3:3)	1.07	0.99	156.4
T_{13} - Mustard + Potato (3:3)	0.99	0.95	145.9
SEm ±	0.029	0.028	4.4
CD (P=0.05)	0.085	0.083	13.2

Relative crowding coefficient

In different intercropping systems, the higher RCC was recorded in mustard + radish 3:3 (1.79) while the lowest RCC value was recorded in mustard + potato 2:2 (0.86) and it was on par with mustard + potato 3:3 (0.95) (Table-4).

Observations revealed that RCC value of mustard was greater than 1, indicating yield advantage over sole cropping and RCC value of intercrops also greater than 1, indicating yield advantage over sole cropping, but in mustard + potato 2:2 and 3:3 (0.86 and 0.95, respectively) recorded less than 1 indicating potato is aggressive than mustard which was due to potato being an exhaustive crop. Similar results were found in intercropping on the basis of RCC by Panda *et. al.* (2022) and Chongtham *et. al.* (2018).

Aggressivity

The highest value of aggressivity was recorded in mustard + radish 3:3 (0.213) and lowest was observed in mustard + potato 3:3 (0.07) (Table-4) indicating mustard crop relatively dominant over root vegetables, whereas associated intercrops like radish was appeared to be dominated. Aggressivity of all treatments followed the trend as, $T_{10}>T_6>T_{12}>T_8>T_{13}>T_{11}>T_7$.

Positive value of aggressivity indicates dominant while negative value indicates dominated crop. Positive values of aggressivity of mustard in mustard + radish and mustard + carrot in both 2:2 and 3:3 row proportions due to efficient utilisation of nutrients by mustard crop as companion crops posed less competition. Similar results were reported by several workers (Singh and Bohra, 2012 and Singh *et al.*, 2016). Conversely, potato and beetroot crops emerged as dominant crops in mustard + potato and mustard + beetroot in 2:2 and 3:3 row proportions, respectively as which are being exhaustive crops offered more competition to the main crop.

Area time equivalent ratio (ATER)

In different intercropping systems, highest ATER was recorded in mustard + beetroot 3:3 (0.99) and mustard + carrot (0.99), while the lowest was recorded in mustard + radish 2:2 (0.89) and remaining treatments were statistically on par with each other following the trend as, $T_{11}=T_{12}>T_7=T_8>T_3>T_9>T_{10}>T_6$.

ATER values were recorded to be almost equal to one as replacement series was employed in the intercropping systems. Therefore, intercropping systems were observed to be advantageous compared to pure stand cropping due to the development of temporal and spatial complementarity. Similar results were reported by Kheroar and Patra (2014) and Seran *et al*. (2009).

Table 4: Aggressivity and relative crowding coefficient as influenced by mustard intercropping with root vegetables

Treatments	Aggressivity		Relative crowding coefficient		
	Aab (MC)	Aba (IC)	Ka (MC)	Kb (IC)	K=Ka *kb
T_6 - Mustard + Radish (2:2)	0.188	-0.188	1.57	1.07	1.67
T_7 - Mustard + Beetroot (2:2)	-0.115	0.115	0.95	1.20	1.14
T_8 - Mustard + Carrot (2:2)	0.046	-0.046	1.19	1.08	1.28
T_9 - Mustard + Potato (2:2)	-0.007	0.007	0.92	0.93	0.86
T_{10} - Mustard + Radish (3:3)	0.213	-0.213	1.66	1.07	1.79
T_{11} - Mustard + Beetroot (3:3)	-0.106	0.106	0.97	1.21	1.17
T_{12} - Mustard + Carrot (3:3)	0.056	-0.056	1.22	1.09	1.33
T_{13} - Mustard + Potato (3:3)	-0.034	0.034	0.94	1.01	0.95
SEm ±	0.0007	0.0007			0.036
CD (P=0.05)	0.002	0.002			0.108

Conclusions

The study shown superiority of mustard-based intercropping systems over sole cropping in terms of productivity and resource use efficiency. Among the treatments, mustard + radish (3:3) recorded the highest mustard equivalent yield (3964 kg ha^{-1}), land equivalent ratio (1.14), land use efficiency (159.6%) and relative crowding coefficient (1.79), indicating a clear yield advantage and better utilization of available resources. Mustard + carrot (3:3) and mustard + beetroot (3:3) also performed comparably with higher ATER values (0.99), suggesting efficient use of both space and time. Mustard exhibited dominance in most combinations, particularly with radish and carrot, as reflected by positive aggressivity values, while potato-based systems showed relatively lower performance. Intercropping mustard with radish and carrot in 3:3 row proportion, is more productive and efficient than sole cropping under the conditions of North Telangana Zone.

Competing interests

Authors have declared that no competing interests exist.

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