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Enhancing Pulse Productivity under Rice Based Production System Through Chickpea and Lentil Based Intercropping Systems in North East India

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) and winter (*rabi*) seasons of 2014-15, 2015-16 and 2016-17 at Imphal, Manipur, to study the performance of intercropping chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) with linseed (*Linum usitatissimum* L.) and Indian mustard [*Brassica juncea* (L.) czernj. & cosson] under 2 varying preceding *kharif* lowland rice (*Oryza sativa* L.) crop durations and also to evaluate the system productivity and profitability. Planting of medium duration rice variety enhanced growth and yield of *rabi* crops resulting in increase in system productivity in terms of rice equivalent yield (REY) and production efficiency (PE) by 5.4% and 14.5%, respectively over planting of late duration rice variety. Seed and biological yields of chickpea, lentil, Indian mustard and linseed were higher in sole cropping than in intercropping systems. Indian mustard and linseed were found dominant and aggressive as compared to chickpea and lentil. Chickpea and Indian mustard intercropping under 4:2 ratio proved more remunerative and recorded higher yield advantage than either of chickpea and linseed or lentil and Indian mustard intercropping as judged by REY (9.7 tonnes/ha), crop productivity (39.9 kg/ha/ day) and net return (` 81,168/ha). Land equivalent ratio (LER) of chickpea with Indian mustard (1.10) remained at par with intercropping chickpea with linseed (1.17), however, lentil intercropped with Indian mustard had less than unity LER of 0.87.

Key words: Chickpea, Intercropping, Land-equivalent ratio, Land-use efficiency, Production efficiency, Rice equivalent yield.

INTRODUCTION

India has achieved self sufficiency in production of food grains but the deficit in the production of oilseeds and pulses is a matter of great concern. The area expansion is difficult in traditional oilseeds and pulses growing regions due to the presence of other competitive crops. However, large areas in North Eastern Region (NER) of India remain fallow (approx. 2.50 million hectare) after the rainy season (June-October) rice (*Oryza sativa* L.) due to various reasons such as cultivation of long duration rice varieties, water logging and excessive moisture in lowland areas, lack of moisture at planting time of winter crops, lack of irrigation, non-availability of seeds of short duration varieties of *rabi* crops and other socio economic problems like cattle menace. Inclusion of short duration low water requiring legumes and oilseeds offers excellent opportunity to utilize carry-over residual soil moisture in these rice fallow areas.

Normally pulse and oilseed crops are raised under rainfed conditions with low input and poor management practices leading to lower productivity level. Therefore, the need for introducing new technologies for increasing and sustaining the yield in rainfed areas can hardly be over emphasized. Intercropping is an old and widespread practice used in low input cropping systems. Intercropping offers opportunity for utilizing niche differences between crop species when the intercropped species have different resource requirements in time and/or space, or when one species is able to provide resources to the other. Intercropping enhances crop diversity which has been declining as development of modern intensive agriculture has proceeded and also increases utilization of resources *i.e*. land, space, light, water and nutrients. However, other agricultural benefits of intercrops include reduction in pests, diseases, weeds, nitrate leaching, soil erosion, improved ground cover, higher nutrient retention, yield advantage and enhanced water-use efficiency. Depending on mixed crops, competition for light, water and nutrients, or allelopathic effects that may occur between mixed crops may also reduce yields. The intercropping not only helps to solve the problem of pulses and oilseed production but also helps to bring additional income to farmers and to get higher income benefits with lower cost of cultivation and helps to utilize the growth resources, time (duration) very efficiently and numerically the land usage can be intensified (Vishwanathan *et al*., 2011). Nowadays, pulse crops such as chickpea, lentil

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have been found successfully intercropped mainly with rapeseed-mustard and linseed under various agro climatic zones of the country in conserved soil moisture. Intercropped oilseed and pulse crops may have the potential for a more efficient use of resources compared to sole crop. Considering such scope of oilseed and pulses cultivation in rice fallow areas of north east India, this experiment was conducted to find the most productive, resource-use-efficient and remunerative rice-pulse based intercropping systems.

MATERIALS AND METHODS

A field experiment was carried out in a sub-tropical climate of Imphal valley consecutively for three years (2014-15 to 2017-18) at Research Farm, Andro, (24°76′ N, 94°05′ E, 790 m above the mean sea-level), Central Agricultural University, Imphal. The soil was clayey, strongly acidic (pH 5.2), high in organic carbon (1.02%), medium in available nitrogen (313 kg/ha), available P_2O_5 (22 kg/ha) and available K_2O (236 kg/ha). The experiment was conducted covering 2 seasons and laid out in split plot design in which two rice varieties of different maturity periods were kept as main plots during *kharif* season and seven cropping systems during *rabi* seasons as sub plots *viz*. sole chickpea, sole Indian mustard, sole lentil, sole linseed, chickpea + linseed (4:2), chickpea + Indian mustard (4:2) and lentil + Indian mustard (4:2) with 3 replications. Late maturity rice variety CAU-R1 (135 days) and early to medium maturity rice variety CAU-R3 (115 days) were used as test crops during *kharif* season. Rice was sown on June 25 and transplanted on July 20 (25 days old seedlings with 2/3 seedlings /hill at 20 cm x10 cm spacing). CAU-R3 was harvested on October 20 and CAU-R1 on November 9.The succeeding *rabi* crops were sown after conventional tillage (2 times harrowing followed by planking) on November 2 in medium duration CAU-R3 plot and on November 20 in late duration CAU-R1 plot. JG-16 (chickpea), HUL-57 (lentil), NRCHB-101 (mustard) and Meera (linseed) were used as test crops. The recommended nutrients of chickpea (20:40:20 NPK kg/ha), Indian mustard (40:20:20 NPK kg/ha), lentil (20:40:20 NPK kg/ha) and linseed (50:40:40 NPK kg/ha) were applied with equal distribution to both the crops as basal application at the time of sowing in lines below the seed. Furrows were opened manually with the help of liners at a specified row-to-row distance of 30 cm and seeds were sown at 10 cm apart plant to plant. Land equivalent ratio (LER), aggressivity (A) and relative crowding coefficient (RCC) were worked out as per procedure given by Mead and Willey (1980), Mc Gilchrist (1965) and De Wit (1960). Land-use efficiency (LUE) and production efficiency (PE) were also calculated as per standard methods. The system productivity expressed as rice equivalent yield (REY) was calculated as

$$REY = Y \text{ rice} + \frac{Y \text{ sole crops or (base crops + inter crops)} \times P \text{ sole crops or (base crops + inter crops)}}{P \text{ rice}}$$

Where,

Y = yield of grain or seed, (kg/ha) and P = price for grain or seed (`/kg).

RESULTS AND DISCUSSION

Crop productivity

Among the growth and yield attributes, higher dry matter per plant and pods/ plant of chickpea and lentil were obtained owing to advancement of planting time of *rabi* crops resulting from the use of medium duration rice variety CAU-R3 in preceding *kharif* season thereby vacating the land for early planting of *rabi* crops but plant height and 100 seeds weight remained unaffected. Increased dry matter accumulation had been reflected in higher grain under early *rabi* crops planting resulting from use of medium duration rice variety in preceding *kharif* season. Also use of medium duration rice variety CAU-R3 during the preceding *kharif* season had significant effect on plant height, dry matter /plant, siliquae/ plant, 100 seeds weight and seed yield of Indian mustard. However, capsules/ plant and 100 seeds weight remained unaffected in linseed though plant height, dry matter/plant and seed yield of linseed were significantly increased due to use of medium duration rice variety rather than late duration rice variety (Table 1).

Intercropping did not affect plant height and 100 seeds weight except dry matter/plant and pods or capsules/plant of chickpea, mustard, lentil and linseed that were significantly higher under sole stands (Table 1). This might be due to presence of competition between main crop and the intercrop for growth resources such as nutrients, moisture and solar radiation because of exhaustive nature of Indian mustard and linseed (Jana *et al.,* 1995; Singh and Rana, 2006). The highest seed yields of all the crops were observed under their sole stands which might be due to greater accumulation of dry matter in sole stands than mixed stands (Table 1). Similar findings were reported by Singh and Rana (2006) and Kour *et al*. (2016). Compared to its sole stand, yield reduction in chickpea was to the tunes of 13.4% and 28.3% under chickpea+linseed and chickpea+Indian mustard intercropping systems, respectively. However, there was 69.9% yield reduction in lentil when intercropped with Indian mustard compared to its sole stand. These reductions in yield were mainly due to the replacement of areas to linseed and Indian mustard by 33.3%.

Use of medium duration rice resulted in the advancement of planting time of *rabi* crops. Because of this advancement of planting time, the system productivity in term of rice-equivalent yield (REY) was increased (5.5%) (Table 2). This was simply because of positive effect of early planting of *rabi* crops. Cropping systems exhibited measurable improvements in total system productivity in terms of REY as compared to either of sole cropping. Chickpea intercropped with Indian mustard gave the highest REY followed by chickpea + linseed. This might be owing to higher yield of Indian mustard. The lowest rice-equivalent

Table 1: Growth, yield attributes and yield of chickpea, mustard, lentil and linseed as influenced by rice crop duration and *rabi* cropping system (pooled mean of 3 years).

Treatment	Chickpea					Mustard					Lentil					Linseed				
	Plant height (cm)	Dry matter /plant (g)	Pods /plant	100 seeds weight (g)	Seed yield (kg/ ha)	Plant height (cm)	Dry matter /plant (g)	Siliquae /plant	100 seeds weight (g)	Seed yield (kg/ ha)	Plant height (cm)	Dry matter /plant (g)	Pods /plant	100 seeds weight (g)	Seed yield (kg/ ha)	Plant height (cm)	Dry matter /plant (g)	Capsules /plant	100 seeds weight (g)	Seed yield (kg/ ha)
Rice Duration																				
Medium	28.8	11.5	28.1	19.2	1156.1	78.5	17.2	92.8	0.59	805.1	17.3	5.8	33.9	2.65	467.9	39.0	6.7	43.0	0.70	320.1
Late	25.1	7.8	18.4	19.3	808.8	58.8	10.4	70.4	0.54	533.0	17.5	4.7	24.9	2.62	328.1	42.7	4.7	37.5	0.70	226.0
Sem(±)	**1.0**	**0.2**	**0.2**	**0.3**	**27.8**	**1.2**	**0.3**	**1.2**	**0.01**	**22.6**	**0.5**	**0.1**	**0.1**	**0.01**	**6.3**	**0.7**	**0.1**	**1.4**	**0.02**	**4.0**
CD(p=0.05)	**NS**	**1.0**	**1.3**	**NS**	**169.1**	**5.2**	**1.5**	**7.3**	**0.03**	**137.3**	**NS**	**0.6**	**0.9**	**NS**	**38.3**	**3.3**	**0.3**	**NS**	**NS**	**24.2**
Cropping System																				
Sole chickpea	27.8	10.9	25.1	19.2	1107.5															
Sole Mustard						73.1	18.2	89.2	0.55	1114.1										
Sole Lentil											17.4	5.6	31.3	2.68	501.1					
Sole Linseed																40.3	6.1	42.5	0.72	382.5
Chickpea+ Linseed (4:2)	26.5	9.5	22.7	19.2	976.3											41.4	5.2	38.0	0.69	163.6
Chickpea+ Mustard (4:2)	26.6	8.6	22.1	19.3	863.4	62.4	12.9	76.9	0.58	451.6										
Lentil+ Mustard (4:2)						70.4	10.3	78.7	0.57	441.5	17.4	4.8	27.5	2.60	294.9					
Sem (±)	**1.6**	**0.3**	**0.4**	**0.4**	**36.3**	**3.6**	**1.2**	**2.0**	**0.01**	**33.0**	**0.5**	**0.1**	**0.2**	**0.04**	**7.7**	**1.7**	**0.2**	**0.5**	**0.01**	**3.2**
CD (p=0.05)	**NS**	**0.43**	**1.3**	**NS**	**88.4**	**NS**	**2.97**	**5.5**	**NS**	**86.8**	**NS**	**0.44**	**0.7**	**NS**	**30.4**	**NS**	**0.54**	**2.0**	**NS**	**12.6**

yield was obtained in lentil+ mustard which was mainly due to lower yield of lentil.

Production efficiency

The system efficiency was also assessed through land-use efficiency (LUE) and production efficiency (PE) based on rice-equivalent yield (REY). Medium duration rice resulted in significantly higher productivity of the system by a margin of 4.56 kg/ha/day over late duration rice. This was simply due to higher REY realized under medium duration rice treatment. Productivity/unit land of chickpea + Indian mustard was higher than of their monocultures and other intercropping systems (Table 3) . This might be attributed to the temporal complementarities as the demand for nutrients and moisture by the component crops was at different times. The short stature of the grain legumes helped Indian mustard plants utilize more light. Among the sole crops, sole chickpea recorded higher value of production efficiency, followed by sole mustard while relatively lower value of production efficiency was recorded with sole linseed followed by sole lentil.

Land-use efficiency

The LUE was recorded higher under medium duration rice planting than late duration rice planting. This was owing to higher crop duration which in turn recorded the highest LUE and efficient utilization of land over normal late duration rice planting. The higher value of land use efficiency was

Table 2: System productivity and economics of rice-based cropping systems as influenced by rice crop duration and *rabi* cropping system (pooled mean of 3 years).

Treatment	Rice equivalent yield (t/ha)	Gross returns (`/ha)	Net returns (`/ha)	B:C
Rice Duration				
Medium	8.45	126806	62154	1.96
Late	8.01	120200	55548	1.86
Sem(±)	**0.07**	**1053**	**1053**	**0.02**
CD(p=0.05)	**0.43**	**6409**	**6409**	**0.10**
Cropping system				
Sole chickpea	9.08	136233	69061	2.03
Sole Mustard	7.86	117958	59277	2.01
Sole Lentil	7.18	107673	41401	1.62
Sole Linseed	6.57	98548	34044	1.53
Chickpea+ Linseed (4:2)	9.30	139570	73064	2.10
Chickpea+ Mustard (4:2)	9.75	146219	81168	2.25
Lentil+ Mustard (4:2)	7.89	118318	53943	1.84
Sem (±)	**0.12**	**1796.95**	**1796.95**	**0.03**
CD (p=0.05)	**0.35**	**5244.12**	**5244.12**	**0.08**

Table 3: Production efficiency (PE), Land use efficiency (LUE), Land Equivalent Ratio (LER), Agressivity(A), Competition Ratio (CR), Relative crowding coefficient (RCC) and Monetary Advantage Index (MAI) of the intercropping systems as influenced by rice crop duration and *rabi* cropping system (pooled mean of 3 years).

Treatment	PE	LUE	LER	A		CR		RCC			MAI
	(kg/ha/day)	(%)		Pulse	Intercrop	Pulse	Intercrop	Pulse	Intercrop	System	
Rice Duration											
Medium	35.93	64.58	1.07	-1.84	1.84	0.70	1.94	1.74	3.09	4.83	11401.50
Late	31.37	70.06	1.03	-1.87	1.87	0.72	1.99	1.86	3.55	5.41	5628.80
Sem(±)	**0.30**		**0.01**	**0.03**	**0.03**	**0.03**	**0.02**	**0.27**	**0.33**	**0.46**	**351.90**
CD(p=0.05)	**1.83**		**0.05**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**2.82**	**2141.00**
Cropping system											
Sole chickpea	37.19	67.12									
Sole Mustard	34.30	63.01									
Sole Lentil	29.99	65.75									
Sole Linseed	25.29	71.23									
Chickpea+ Linseed (4:2)	35.89	71.23	1.17	-2.06	2.06	0.87	1.37	2.51	4.93	7.44	14957.90
Chickpea+ Mustard (4:2)	39.91	67.12	1.11	-1.43	1.43	0.69	1.46	2.18	2.29	4.47	12487.90
Lentil+ Mustard (4:2)	32.97	65.75	0.87	-2.06	2.06	0.57	3.07	0.71	2.75	3.46	-1900.40
Sem (±)	**1.50**		**0.02**	**0.15**	**0.15**	**0.03**	**0.16**	**0.31**	**0.63**	**0.64**	**1059.00**
CD (p=0.05)	**4.38**		**0.08**	**NS**	**NS**	**0.08**	**0.51**	**1.01**	**NS**	**2.08**	**3453.10**

achieved in intercropping systems over their monocultures. This could be attributed to the increased light interception, reduced water evaporation that improved conservation of the soil moisture in intercropping treatments compared to sole cropping. These results confirm the findings of Ghanbari *et al.* (2010), who also reported that intercropping systems have been found to enhance land-utilization efficiency.

Land-equivalent ratio

Land-equivalent ratio (LER) is relative land area under sole crops required to produce the same yield as obtained under their intercropping and the land-equivalent ratio of more than unity expresses that the biological efficiency of such systems is higher. The values of land-equivalent ratio in all the intercropping systems were greater than unity except lentil + Indian mustard, indicating intercropping advantage in comparison with respective monocultures. The LER of different intercropping treatments revealed that the intercropping of chickpea + linseed and chickpea + Indian mustard were found biologically more efficient than lentil + Indian mustard (having less than unity) which is quite obvious from their LER values of 1.17 and 1.11. It indicated 17% and 11% higher yield advantage in chickpea + linseed and chickpea + Indian mustard intercropping systems, respectively as compared to their sole cropping. It might be attributed to the better development of both the temporal and spatial complementary relationships between chickpea and Indian mustard or chickpea and linseed, leading to better use of growth resources. Similar findings on chickpea (*Cicer arietinum*) + Indian mustard (*Brassica juncea*) intercropping system were reported by Kour *et al.* (2015).

Aggressivity

The competitive ability of the component crops in an intercropping system is determined by its aggressivity value (Table 3). The zero value of aggressivity indicates that component crops are equally competitive. For any other situation, both crops will have the same numerical value but the sign of the dominant species will be positive and that of dominated negative. The greater the numerical value, the bigger the differences between actual and expected yields, *viz*. the component crops did not compete equally. Among the intercropping treatments, positive values in Indian mustard and linseed crops while negative values in chickpea and lentil crops were recorded. This trend showed that Indian mustard and linseed were the dominant crops and chickpea and lentil were dominated crops. This probably happened owing to early suppressive ability of the fast growing high foliage Indian mustard and linseed crops along with its better ability to intercept light and also utilize soil resources which enabled them to become more efficient in resource utilization as compared to chickpea and lentil crops. Such findings were reported by Lal (2012) on Ethiopian mustard + chickpea intercropping system under dryland conditions.

Competitive ratio

The competition ratio (CR) which measures the degree with which one crop competes with the other also showed that linseed and mustard having higher values are more competitive than chickpea or lentil. The CR value for chickpea and lentil are less than unity, indicating that there were positive benefits of chickpea and lentil on the component crops (linseed and Indian mustard) and these species can be grown in an intercrop. Linseed and Indian mustard had relatively rapid initial growth leading to stiff competition for resources particularly nutrients, moisture and space which persist for the whole cropping period (Padhi *et al.,* 2010).

Relative crowding coefficient

The intercropped linseed and Indian mustard had higher relative crowding coefficient than chickpea and lentil indicating both of them are to be more competitive than chickpea and lentil, agreeing with the CR values reported earlier. The products of relative crowding coefficients in both the intercropping systems were higher than unity indicating that there was a yield advantage having a complementary relationship. It might also be due to exhaustive and dominant effect of linseed and Indian mustard over chickpea and lentil which created inter and intra-specific competition than sole crops. Ahlawat *et al*. (2005) and Tripathi *et al*. (2005) reported similar results for relative crowding coefficient in chickpea based intercropping systems.

Monetary advantage index

Monetary advantage index (MAI) values of intercropping systems except lentil + Indain mustard were positive which showed a definite yield advantage in chickpea + linseed and chickpea + Indian mustard intercropping systems as compared to sole cropping. These results also support the findings of (Padhi *et al.,* 2010) who found that when the LER and LEC were higher there was also significant economic benefit expressed with higher MAI values.

Economics

Planting of medium duration rice variety was found to be more remunerative, as evident from higher net returns along with higher benefit: cost ratio than planting of late duration rice variety. Chickpea + Indian mustard intercropping system fetched higher net returns as well as B: C ratio not only over sole crops but also chickpea + linseed and lentil + Indian mustard intercropping systems due to more combined yield (Table 2). This might be due to beneficial effect of intercropping system which resulted in more system productivity in term of rice equivalent yield. Similar results were reported by Singh and Rana (2006). It can be concluded that chickpea + mustard intercropping system proved to be the most promising system which obtained more net returns and benefit:cost ratio. Thus it may be recommended to farmers who are interested in taking both the crops instead of their pure stands as it proved to be economically better and feasible in generating more monetary benefits by spending fewer amounts for their better livelihood security as well as land-use efficiency.

CONCLUSION

Planting of medium duration rice variety had pronounced effect on growth, productivity and profitability of the rice-based cropping systems in rainfed lowland agro-ecosystem. Adoption of chickpea + Indian mustard intercropping system (4:2) under rice fallow conditions would be a better option to sustain the productivity and profitability of rice based production system in North East India.

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