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Reaya Chanu Laishram
Department of Agronomy, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Utlou, Bishnupur, Manipur, India

Sakhen Sorokhaibam
KVK, Utlou, Bishnupur, Manipur, India

Olivia Chanu Leitam
Department of Agronomy, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Utlou, Bishnupur, Manipur, India

Merinda Wangkheirakpam
Department of Agronomy, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Utlou, Bishnupur, Manipur, India

CH Narendrajit
Central Agricultural University, Imphal, Manipur, India

Corresponding Author:
Reaya Chanu Laishram
Department of Agronomy, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Utlou, Bishnupur, Manipur, India

Yield, economics and biological indices of chickpea + rapeseed intercropping system as influenced by moisture conservation and nutrient management practices under rainfed conditions

Reaya Chanu Laishram, Sakhen Sorokhaibam, Olivia Chanu Leitam, Merinda Wangkheirakpam and CH Narendrajit

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Abstract
A field experiment was conducted during *rabi* season of 2018-2019 at the experimental field of Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences located at Utlou, Bishnupur District, Manipur to assess the yield, economics and biological indices of chickpea + rapeseed (4:2) intercropping system with suitable moisture conservation practices and different levels of phosphorus and sulphur under rainfed conditions in order to evaluate the intercropping system and analyze the competition and the interrelationship between component crops and their pure stands. Chickpea + rapeseed intercropping system (4:2) recorded higher chickpea equivalent yield over sole chickpea and sole rapeseed with the application of moisture conservation and phosphorus and sulphur fertilizer. The chickpea equivalent yield and system productivity index values were greater with moisture conservation practices and higher dose of phosphorus and sulphur nutrition indicating an advantage of intercropping. In intercropping, the values of aggressivity and competitive ratio indicated that chickpea was more competitive than rapeseed. This study suggests that chickpea/rapeseed (4:2) intercropping system was more productive and profitable with phosphorus and sulphur nutrition if proper moisture conservation practice could be adopted by the farmers as alternative options under rainfed conditions.

Keywords: Intercropping, sole, FYM, straw mulch, hydrogel, phosphorus, sulphur, control

Introduction
Pulses are one of the economic sources of protein in India. The share of pulses to total food grain basket is around 9.00-10.00 per cent and is a critical and inexpensive source of plant-based proteins, vitamins and minerals. India, with more than 29 mha pulses cultivation area, is the largest pulse producing country in the world. It ranks first in area and production with 34.00 per cent and 26.00 per cent respectively. Chickpea or chana or bengal gram is the most important winter legume in India belonging to the family fabaceae. It is the third most important pulse crop that plays a vital role in global agricultural economy (FAO, 2012) [4]. Oilseeds are among the major crops that are grown in the country apart from cereals. Rapeseed-Mustard is the most important oilseed crop in India after groundnut. Biologically, the rapeseed and mustard plants belongs to the family cruciferae and under the genus *Brassica* with large number of species and sub species cultivated in India. The oil content varies from 37.00 to 49.00 per cent. Used as edible oil, seed as condiment, young plants and leaves as green vegetable, the oilcakes is used as cattle feed and manures.
Intercropping can be defined as the production or growing of two or more crops simultaneously in the same piece of land (Ofori and Stern, 1987) [10] in a distinct row arrangement using one crop as a base crop to which rows of an additional component crop is added. The major considerations for intercropping are the contrasting maturities, growth rhythm, height and rooting pattern and variable insect pest and disease associated with component crops so that these complement each other rather than compete for the resources and guard against weather adversaries. Moreover, intercropping improves soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation through greater ground cover than sole cropping and provides better lodging resistance for crops susceptible to lodging than when grown in monoculture.

The major constraint limiting the productivity of pulses and oilseeds is that they are predominantly raised under energy-starved conditions (on poor fertile lands). Poor nutrient management is an important reason of low productivity of chickpea and rapeseed. Limited availability of soil moisture at critical stages of crop growth and poor fertility are the major constraints. The potential of chickpea has not explored much in Manipur. Hence, an experiment was conducted to evaluate the yield, economics and biological indices of chickpea and rapeseed as sole and intercrop as influenced by moisture conservation and nutrient management practices under *rainfed* conditions.

Materials and Methods

A field experiment was conducted during *rabi* season of 2018-2019 at the experimental field of Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences located at Utlou, Bishnupur District, Manipur. The soil of the experimental site was clayey loam in texture with slightly acidic soil reaction (pH 5.5) having high organic carbon (1.41%) with medium available nitrogen (288.51 kg/ha), medium available P_2O_5 (47.17 kg/ha) and medium available K_2O (260.00 kg/ha). The experiment was laid out in split split plot design with 18 treatments combinations, *viz*. three cropping systems (C_1 - sole chickpea, C_2 - sole rapeseed and C_3 - chickpea + rapeseed (4:2) intercropping) in main plots; two moisture conservation practices (M_0 - control and M_1 - FYM @5t/ha + straw @2t/ha + hydrogel@5kg/ha in sub plots; three fertility levels (F_0 - control, F_1 - 20kg P_2O_5 + 15kg S/ha and F_2 - 40kg P_2O_5 + 20kg S/ha) in sub-sub plots. Sole chickpea (JG-14) and sole rapeseed (M-27) were sown at uniform row spacing, i.e 30 and 10 cm apart during winter season using 60 and 10 kg/ha seed rate, respectively. Full dose of nitrogen, phosphorus, potassium and sulphur as per treatments recommendation applied through Urea, MOP and SSP respectively just before sowing of crops. The seeds of both chickpea and rapeseed were treated with *Trichoderma harzianum* @ 5 g/kg of seed, the night before sowing. The rapeseed crop was harvested on 16th March, 2019 and the chickpea crop was harvested on 10th May, 2019. After threshing seed yield and stover yield were taken in kg/ha. The data were subjected to analysis of variance (ANOVA) in split 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 treatments mean. The other production potential parameters were calculated as follows:

Harvest index (HI)

$$HI = \frac{\text{Economic yield(kg/ha)}}{\text{Biological yield(kg/ha)}} \times 100$$

Chickpea equivalent yield (CEY)

$$CEY = \frac{\text{Grain yield of rapeseed(kg/ha)}}{\text{Market price of chickpea (Rs/kg)}} \times \text{Market price of rapeseed (Rs/kg)}$$

Land equivalent ratio (LER)

LER is the relative land area under sole crops that is required to produce the yields achieved in intercropping.

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb} = La + Lb$$

Where, Yaa = yield of component a as sole crop, Ybb = yield of component b as sole crop, Yab= yield of component a as intercrop grown in combination with component b, Yba= yield of component b as intercrop grown in combination with component a.

Monetary Advantage Indices (MAI)

$$MAI = \frac{LER-1}{LER} \times \text{Combined value of intercrop}$$

Aggressivity (A)

Aggressivity (A) indicates that the relative yield increase in "a" crop is greater than of "b" crop in an intercropping system (McGilchrist, 1965). The agressivity can be derived from the following formula.

A chickpea = {Yab / (Yaa x Zab)} -{Yba / (Ybb x Zba)}
A intercrops = {Yba / (Ybb x Zba) } -{Yab / (Yaa x Zab)}

Where, Yab = the yield of chickpea in intercropping, Yba = the yield of intercrop in intercropping, Zab = sown proportion of chickpea in intercropping, Zba = sown proportion of intercrop in intercropping, Yaa = the yield of chickpea in sole cropping, Ybb = the yield of intercrop in sole cropping.

Competitive ratio (CR)

Competitive ratio gives better measure of competitive ability of the crops and is also advantageous as an index over K and A (Willey and Rao, 1980) [15]. The CR simply represents the ratio of individual LERs of the component crops and takes into account the proportion of the crops is sown.

CR chickpea = (LER chickpea/ LER intercrop) (Zba /Zab)
CR intercrop = (LER intercrop / LER chickpea) (Zab / Zba)

Where, Zab = sown proportion of chickpea in combination with intercrops, Zba = sown proportion of intercrop in combination with chickpea

Result and Discussion

Yield of chickpea and rapeseed as influenced by moisture conservation practices and fertility levels under sole and intercropping system

Chickpea seed and stover yield in sole cropping were significantly higher over chickpea + rapeseed (4:2) intercropping (Table-1), presumably due to higher population in sole chickpea. Similar result was reported by Singh and Mahesh (1993) [13]. Moisture conservation practices also significantly influenced the seed and stover yield during the year of experimentation. Application of FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha was observed higher yield over control. Seed and stover yield was significantly influenced with successive fertility levels over control. Effect of sulphur and phosphorus application on growth and yield of chickpea was statistically significant (Singh *et al*., 2003) [14]. Highest seed yield (969.28 kg/ha) and stover yield (1752.19 kg/ha) was obtained with 40 kg P_2O_5 + 20 kg S/ha followed by 20 kg P_2O_5 + 15 kg S/ha and lowest seed and stover yield was obtained from control. Harvesting index does not show significant variation among cropping system, moisture conservation practices and fertility levels.

In Rapeseed seed and stover yield was found significantly influenced by cropping system. Higher seed and stover yield was found with sole rapeseed over the chickpea + rapeseed intercropping (Table-1), may be due to less competition for light, water and nutrient in sole rapeseed over chickpea + rapeseed intercropping. Similar results were reported by Das *et al*. (1992) [3]. Moisture conservation also significantly influenced seed yield. Application of FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha produced higher seed and stover yield over control. In rapeseed, increased in fertility levels also increased the seed and stover yield. Highest seed yield (564.24 kg/ha) and stover yield (1315.06 kg/ha) was obtained from 40 kg P_2O_5 + 20 kg S/ha followed by 20 kg P_2O_5 + 15 kg S/ha. Bharose *et al*. (2011) [2] also have reported that increased in level of phosphorus from 25 kg/ha to 50 kg/ha resulted in a significant increased in the seed yield. Harvesting index does not show significant variation among cropping system, moisture conservation practices and fertility levels.

LER were found higher on intercropping system which show yield advantages over monocropping due to better utilization of available land. Chickpea + Rapeseed (4:2) intercropping system obtained highest LER (1.32) which show that the 13.00% advantages over sole cropping (Punia *et al.*, 1999) [11]. Application of FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha does not significantly influenced the LER. Fertility levels were also found non-significant during the experimentation. However, P and S fertilizer slightly show increased in LER over control.

CEY was obtained highest in chickpea + rapeseed intercropping as compared to either sole cropping (Table-1). Similar results were reported by Ravikumar *et al*. (2006) [12]. Moisture conservation system show remarkably increased in CEY as compared to control. P and S fertilizer significantly improved CEY of chickpea + rapeseed intercropping system. Application of 40 kg P_2O_5 + 20 kg S/ha showed highest CEY followed by 20 kg P_2O_5 + 15 kg S/ha. Lowest LER was obtained from control during experimentation.

Table 1: Yield of chickpea and rapeseed as influenced by moisture conservation practices and fertility levels under sole and intercropping system

Treatments	Seed yield (kg/ha)		Stover yield (kg/ha)		Harvest index (%)		LER	CEY (kg/ha)
	Chickpea	Rapeseed	Chickpea	Rapeseed	Chickpea	Rapeseed		
Cropping system								
C_1: Chickpea	915.19		1644.13		36.65		1.00	915.19
C_2: Rapeseed sole		640.50		1341.33		33.44	1.00	457.50
C_3: Chickpea + Rapeseed	691.41	372.84	1182.47	1099.63	35.82	27.23	1.32	957.72
SEm±	0.45	1.10	1.82	4.14	0.16	0.06	0.01	0.95
CD (P=0.05)	2.71	6.74	11.07	25.16	NS	NS	0.04	3.73
Moisture conservation practices								
M_0: Control	758.17	477.26	1320.11	1133.87	36.22	29.87	1.11	732.71
M_1: FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha	848.43	536.08	1506.49	1307.09	36.26	30.80	1.10	820.90
SEm±	2.02	0.80	3.07	4.64	0.14	0.04	0.01	1.36
CD (P=0.05)	7.95	3.00	12.06	18.21	NS	NS	NS	4.70
Fertility levels								
F_0: Control	649.73	427.90	1104.20	1110.36	36.39	29.69	1.10	636.89
F_1: 20 kg P_2O_5 + 15 kg S/ha	790.88	527.29	1383.51	1236.03	35.62	30.38	1.09	778.64
F_2: 40 kg P_2O_5 + 20 kg S/ha	969.28	564.24	1752.19	1315.06	36.71	30.93	1.13	914.88
SEm±	1.81	1.60	2.95	4.06	0.16	0.08	0.01	1.29
CD (P=0.05)	5.41	4.8	8.86	12.17	NS	NS	NS	3.77

*LER - Land equivalent ratio, *CEY - Chickpea Equivalent Yield

Economics of chickpea and rapeseed as influenced by moisture conservation practices and fertility levels under sole and intercropping system

Intercropping of chickpea + rapeseed showed significantly higher gross return, net return and B:C ratio (Table-2) as compared to sole cropping system of chickpea and rapeseed respectively, mainly due to beneficial effect. Similar results were reported by Abraham *et al*. (2010) [1]. Application of FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha recorded significantly higher gross return (57463.00 Rs/ha) and net return (29199.46 Rs/ha) whereas B:C ratio does not show any significant influenced by moisture conservation practices, presumably due to additional cost of FYM, straw and hydrogel. All the fertility level significantly showed higher gross return, net return and B:C ratio over control during the year of experimentation. Similar result was reported by Kumar and Yadav (2007) [8]. 40 kg P_2O_5 + 20 kg S/ha recorded higher gross return (64041.28 Rs/ha), net return (37781.11 Rs/ha) and B:C ratio (1.42) followed by 20 kg P_2O_5/ha + 15 kg S/ha. Lowest value was observed from control.

Table 2: Economics of chickpea and rapeseed as influenced by moisture conservation practices and fertility levels under sole and intercropping system

Treatments	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
Cropping system			
C_1: Chickpea sole	64063.22	36495.22	1.33
C_2: Rapeseed sole	32025.00	9507.00	0.43
C_3: Chickpea + Rapeseed	67041.72	41181.22	1.61
SEm±	66.49	66.49	0.03
CD (P=0.05)	261.07	261.07	0.10
Moisture conservation practices			
M_0: Control	51290.62	28922.83	1.27

M_1: FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha	57463.00	29199.46	0.98
SEm±	95.02	95.02	0.01
CD (P=0.05)	329.81	328.81	0.04
Fertility levels			
F_0: Control	44583.55	20462.38	0.83
F_1: 20 kg P_2O_5 + 15 kg S/ha	54505.11	28939.94	1.12
F_3: 40 kg P_2O_5 + 20 kg S/ha	64041. 28	37781.11	1.42
SEm±	90.47	90.47	0.01
CD (P=0.05)	264.08	264.08	0.04

MAI, Aggressivity and Competitive ratio of chickpea and rapeseed as influenced by moisture conservation practices and fertility levels under sole and intercropping system

MAI values were positive which indicate a definite yield advantage in chickpea + rapeseed intercropping system over sole cropping under all the treatment levels (Table-3). Highest MAI value was obtained with application of FYM @ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha over control. Fertility levels also showed significant improvement over control where the highest MAI value was obtained with 40 kg P_2O_5 + 20 kg S/ha followed by 20 kg P_2O_5 + 15 kg S/ha. Lesser value of MAI was obtained with control. Similar result was reported by Jana *et al*. (1995) [7].

Agressivity value of chickpea + rapeseed was found maximum under control as compared with application of FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha, which showed improvements in the performance of chickpea + rapeseed intercropping system over control treatment (Table-3). In fertility levels, dominant behavior of rapeseed over chickpea (as intercrops) was obtained on control treatment, which indicates that P and S has superior effect on crops performance in chickpea + rapeseed intercropping system.

The CR value of intercropping was higher than chickpea which indicate more dominant nature of rapeseed over chickpea in intercropping system (Table-3). Similar results were reported by Imran *et al.* (2011) [6]. The CR value of chickpea + rapeseed intercropping was found slightly influenced with application of FYM @ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha. Higher CR value was obtained with FYM @ 5 t/ha+ straw mulch@ 2 t/ha+ hydrogel@ 5 kg/ha over control. Whereas, in fertility level higher CR value was obtained in control which indicate more higher competitive of chickpea with intercrop in comparison to other fertility treatment.

Table 3: MAI, Aggressivity and Competitive ratio of chickpea and rapeseed as influenced by moisture conservation practices and fertility levels under sole and intercropping system

Treatments	MAI	Ac	Aic	CRc	CRic
Moisture conservation practices					
M_0: Control	15242.53	-0.65	0.65	0.64	0.92
M_1: FYM@ 5 t/ha + straw mulch@ 2 t/ha + hydrogel@ 5 kg/ha	16597.32	-0.61	0.61	0.65	0.89
SEm±	8.56	0.012	0.012	0.005	0.002
CD (P=0.05)	52.11	NS	NS	NS	NS
Fertility levels					
F_0: Control	16136.70	-0.79	0.79	0.61	1.10
F_1: 20 kg P_2O_5 + 15 kg S/ha	13914.83	-0.56	0.56	0.66	0.79
F_2: 40 kg P_2O_5 + 20 kg S/ha	17708.25	-0.54	0.54	0.67	0.82
SEm±	148.00	0.02	0.02	0.01	0.00
CD (P=0.05)	443.62	0.05	0.05	0.02	0.01

*MAI - Monetary advantages indices, *Ac - Aggressivity chickpea, *Aic - Aggressivity intercrops,*CRc - Competitive ratio chickpea, *CRic - Competitive ratio intercrops

Conclusion

On the basis of present investigation we can conclude that intercropping of chickpea + rapeseed (4:2) was found to be superior over sole chickpea and sole rapeseed. Application of FYM@ 5t/ha + straw@2t/ha + hydrogel@5kg/ha had significantly improved yield of chickpea and rapeseed in sole and intercropping system. Application of 40kg P_2O_5 + 20kg S/ha had significant influence on both chickpea and rapeseed as sole and intercrop. Land equivalent ratio and chickpea equivalent yield were recorded significantly higher in chickpea + rapeseed intercropping over sole chickpea and rapeseed which indicated superiority of intercropping system. Maximum value of aggressivity, competitive ratio was recorded with control. Highest net return and benefit cost ratio were obtained with chickpea + rapeseed intercropping system with application of 40kg P_2O_5 + 20kg S/ha.

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