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Productivity, profitability and energy budgeting of maize (*Zea mays*)/ greengram (*Vigna radiata*) intercropping system under rainfed conditions of Eastern Himalayan Region

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ABSTRACT

A field experiment was conducted at Nagaland during 2009 and 2010 to study the productivity, profitability and energy budgeting of maize [*Zea mays* (L.)]/greengram [*Vigna radiata* (L.) Witczek] intercropping system under rainfed conditions of Eastern Himalayan Region on a sandy loam soil. There was significant superiority in growth and yield attributes as well as yield of maize (3.37 tonnes/ha) and greengram (1.34 tonnes/ha) under sole cropping as compared to their intercropping system. Maize equivalent yield (5.64 tonnes/ha) land equivalent ratio (1.43), Area Time Equivalency Ratio (1.19), Land Equivalent Coefficient (0.49), and Monetary Advantage Indices (₹ 3 273) was significantly higher with intercropping system (1:1, closely followed by 1:2 ratio) over other intercropping system under study. Moreover, higher Crop Performance Ratio (3.81) was recorded with 1:3 maize–greengram intercropping system. Intercropping system recorded the higher net return and B: C ratio as compared to either of the sole cropping. Among different row proportions, 1:1 row ratio recorded maximum energy efficiency (19.1) and energy productivity (1569.4 g/MJ) than other intercropping system.

Key words: Economics, Energy efficiency, Greengram, Intercropping, Maize, *Vigna radiata*, Yield advantage indices and *Zea mays*

Producers and researchers carry out different cropping systems to increase productivity and sustainability by practicing crop rotations, relay cropping, and intercropping of annual cereals with legumes. Intercropping of cereals with legumes has been popular in tropics and rainfed areas of the world (Ghosh 2009) due to its advantages for soil conservation (Dhima *et al*. 2007), yield increment (Chen *et al*. 2004). Different seeding ratios or planting patterns for cereal-legume intercropping have been practiced by many researchers (Dhima *et al.* 2007). Competition among mixtures is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Species or cultivar selections, seeding ratios, and competition capability within mixtures may affect the growth of the species used in intercropping systems in rainfed areas (Carr *et al*. 2004). A number of indices such as land equivalent ratio, relative crowding coefficient, competitive ratio, actual yield loss, monetary advantage, and intercropping advantage have been proposed to describe competition within and economic advantages of intercropping systems (Ghosh *et al*. 2009). The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio energy (Abdi *et al.* 2012). Efficient use of energy is an important indicator of agricultural sustainability. Energy use in agricultural production becomes more intensive. Practices such as irrigation, chemical fertilizer application, heavy machinery use and heated greenhouses consume large amounts of energy (Pimentel 2006). However, such indices have not been used for maize (*Zea mays* L.) and greengram [*Vigna radiata* (L.) Wilczek] intercropping to evaluate the competition among species and also economic advantages of each intercropping system in the Eastern Himalayan Region. The objectives of the present study were (i) to evaluate the systems for better management of resources to obtain less competition among plants, higher productivity, sustainability, and economic value. (ii) To examine different competition indices in these intercropping systems.

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MATERIALS AND METHODS

A field experiment was conducted at Research Farm of ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema during *kharif* season in 2009 and 2010 to study theproductivity, profitability and energy budgeting of maize/greengram intercropping system under rainfed conditions of Eastern Himalayan Region.The experimental site was located between 25.45^0 N latitude 93.53^0 E longitudes with a mean altitude of 295 m above mean sea level. The experimental site comes under sub humid region where monsoon normally starts by the middle of April and extends up to September. The annual rainfall during crop growing season from 5th June to 20th September was 694.7 mm in 2009 and 1235.1 mm during 2010 which was less than annual average rainfall 1570 mm. Temperature and relative humidity during the experiment period ranged from 18 ^{0}C to 35 ^{0}C and 78.5% to 92%, respectively. The soil of the experimental site was sandy loam texture, acidic in reaction with pH 5.4, high in organic carbon 0.80%, low in N 188 kg/ha, moderate in phosphorous 20 kg/ha and low in K 48 kg/ha.

The experiment was conducted in randomized block design in three replications with 7 treatment combinations. The treatment consisted of T_1, sole maize in spacing 60 cm × 20 cm to achieve plant density of 83.3 × 10^3/ha, T_2, sole greengram in spacing 30 cm × 10 cm to achieve plant density of 333.3 × 10^3/ha, T_3, intercropping one row of greengram in between two rows of maize (1: 1) to maintain plant density for maize 83.3 × 10^3/ha (60 cm × 20 cm) and 133 × 10^3/ha (60 cm × 10 cm) for greengram. T_4, intercropping of two rows of maize after one row of greengram (2:1) in a plant density of 66.6 × 10^3/ha each for maize and greengram. T_5, intercropping of three rows of maize after one row of greengram (3:1) in a plant density of 75.0 × 10^3/ha for maize and 33.3 × 10^3 greengram, T_6, intercropping of one row of maize after two rows of greengram (1:2) in a planting density for maize 50 × 10^3/ha and 33.3 × 10^3/ha for greengram. T_7, intercropping of one row of maize after three rows of greengram (1:3) in a planting density for maize 33.3 × 10^3/ha and 200 × 10^3/ha for greengram. The crop was sown when sufficient rain was received (1 June). The intercrop greengram (variety, T-1) was harvested in 10 August and the main crop, maize (Vijay Composite) was harvested in 1 September. The grain and straw were sun dried and data were taken for yield and yield attributing characters.

Farmers are concerned mostly with total profit and the marginal benefit: cost ratio from investment in labour and inputs (Ghosh *et al*. 2009). The yield and economic performance of intercropping was assessed to determine whether maize yield and additional greengram yield were sufficient to convince farmers for practicing intercropping system. For comparing the economical value of systems, the grain yields were converted into gross returns and net returns.

The yields of sole and intercrop greengram was converted to maize equivalent yield (MEY) on financial basis and expressed as MEY = yield of greengram × unit price of greengram/unit price of maize. However, MEY does not indicate the net gain obtained from a cropping system and also does not explain the land use pattern of the cropping systems. Land equivalent ratio (LER) is the relative land area under sole crops that is required to produce the yields achieved in intercropping.The LER value greater than unity reflects the extra advantage of intercropping system over sole cropping system. It was calculated by LER, Yab/Yaa + Yba/Ybb; 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 and Yba, yield of component b as intercrop grown in combination with component a. Crop performance ratio (CPR) was calculated by using the formula- CPR, Qia/Pia × Qsa + Qib/Pib × Qsb, Where, Q ia and ib, Productivity per unit area in the intercrop of a and b, Qsa and Qsb, Productivity per unit area in the sole crops of a and b, Pia and Pib, Proportion of the intercrop area sown with the species a and species b. Area Time Equivalency Ratio, ATER= La×Da+Lb×DbT Where, La (Yab/Yaa) and Lb (Yba/Ybb) are partial LERs of component crops a and b, Da and Db are duration of crops a and b, T is the total duration of the intercropping systems. Monetary Advantage Indices, MAI, LER-1. Land Equivalent Coefficient; LEC, LER × Combined value of intercrops. It is regarded as measure of association or interaction when concerned with the strength of relationship. In intercropping system LEC should be greater than 0.25, i.e. a productivity coefficient (PC) greater than 25%. LEC, LER m × LER ic Where, LER m, Land equivalent ratio of maize; LER ic, Land equivalent ratio of intercrop.

Economics of different treatment was worked out by taking into account the cost of inputs and income obtained from output (grain and stover yield). Net returns (₹/ha) were calculated by using formula = Gross returns – cost of cultivation. Benefit: cost ratio was calculated by used formula = Gross returns/cost of cultivation. Minimum support price (Fixed by Government of India) of maize in 2010 = ₹ 9 800/tonnes, and for greengram ₹ 35 000/tonnes, respectively used for economic analysis. Energy budgeting was done according to Mittal *et al.* (1985) and energy use efficiency and energy productivity were calculated as suggestedby Abdi *et al*. (2012).

RESULTS AND DISCUSSION

Growth and yield attributes

Among all the treatments, the higher growth and yield attributes of maize was observed in the treatment T_6 (Table 1). The number of cob/plant, number of seed/row and number of seed/cob were significantly higher in the treatment T_6 which was closely followed by the treatment T_7 and T_5. This might be due to the plating pattern, which creates dissimilar conditions for plant growth and development of maize and greengram in intercropping system than their sole cropping.

The growth and yield attributing characters of greengram was found to be higher in the treatment T_7 (Table 2). The highest number of pods/plant was significantly higher in T_7 (34.72) over all the treatment. However, it was statistically at par with the treatment T_5 and T_6. This may be

Table 1 Effect of maize + greengram intercropping system on growth and yield attributing characters of maize

Treatment	Plant height (cm)	No of leaves/ plant	No of cobs/ plant	Length of cob	No of row/cob	No of seed/row	No of seed/cob
Sole maize	203.58	12.00	1.61	19.72	15.89	30.72	416.72
Maize + greengram (1:1)	181.8	12.25	1.5	21.12	15.7	31.83	390.48
Maize + greengram (2:1)	194.75	11.67	1.61	21.88	15.95	32.44	447.05
Maize + greengram (3:1)	190.89	11.75	1.83	21.59	16.26	36.11	421.55
Maize + greengram (1:2)	206.00	19.22	2.17	23.57	16.51	39.55	515.95
Maize + greengram (1:3)	183.49	19.00	1.86	22.17	16.32	34.06	509.15
SEm ±	6.94	7.12	0.17	1.12	0.56	2.01	27.26
CD(P=0.05)	NS	NS	0.53	NS	NS	6.05	87.02

Table 2 Effect of maize + greengram intercropping system on growth and yield attributing characters of greengram

Treatment	Plant height (cm)	No of branch/plant	No of trifoliate leaves/plant	Pod/plant	Length of pod	Grain/pod
Sole greengram	65.82	4.6	13.11	22.33	9.19	11.5
Maize + greengram (1:1)	61.67	4.18	12.66	26.9	9.12	12.17
Maize + greengram (2:1)	63.73	3.98	15.17	30.42	9.33	11.15
Maize + greengram (3:1)	64.67	4.38	15.11	34.67	9.98	12.4
Maize + greengram (1:2)	67.43	5.28	19.61	33.35	9.45	12.2
Maize + greengram (1:3)	69.25	5.5	19.88	34.72	10.12	13.25
SEm ±	4.34	0.37	1.45	2.09	0.7	0.69
CD(*P=0.05*)	NS	NS	NS	6.67	NS	NS

because of less competition effect for resources, particularly moisture and nutrients as the plants were widely spaced. These findings are in accordance with Ghosh *et al.* (2009).

Grain yield

The grain yield of intercropped maize decreased by 15.13%, 25.51%, 21.07%, 45.10% and 59.24 % in the intercropping system T_3,T_4,T_5,T_6 and T_7 (Table 3) respectively over maize sole cropping. This might be due to changing of planting pattern with adjustment of row and spacing as well as vary in growth, yield attributes, grain and stover yield of intercropped maize than sole stand of maize. This result is in conformity with the findings of Myaka *et al.* (2006) also emphasized the significantly higher yield in intercropping under non-irrigated environment than sole cropping.

Yield advantage indices

The yield advantage in terms of maize equivalent yield (MEY) was greater in maize/greengram intercropping system than their respective sole cropping (Table 3). On an average, 46.5 and 19.2% more yield advantages in terms of MEY was received from T_3 over sole maize and sole greengram, respectively.

Table 3 Effect of maize + greengram intercropping system on yield, MEY and MAI

Treatment	Maize		Greengram		MAY (tonnes/ha)	MAI (₹/ha)
	Grain yield (tonnes/ha)	Stover yield (tonnes/ha)	Grain yield (tonnes/ha)	Stover yield (tonnes/ha)		
Sole maize	3.37	13.38			3.37	
Sole greengram			1.34	1.96	4.77	
Maize + greengram (1:1)	2.86	11.63	0.78	0.95	5.64	3273
Maize + greengram (2:1)	2.51	8.25	0.48	0.77	4.21	871
Maize + greengram (3:1)	2.66	9.41	0.30	0.68	3.72	111
Maize + greengram (1:2)	1.85	5.78	1.06	1.47	5.63	2684
Maize + greengram (1:3)	1.35	3.91	1.16	1.63	5.49	2161
SEm±	0.08	0.87	0.14	0.09	0.51	
CD(*P=0.05*)	0.25	2.79	0.45	0.27	1.61	

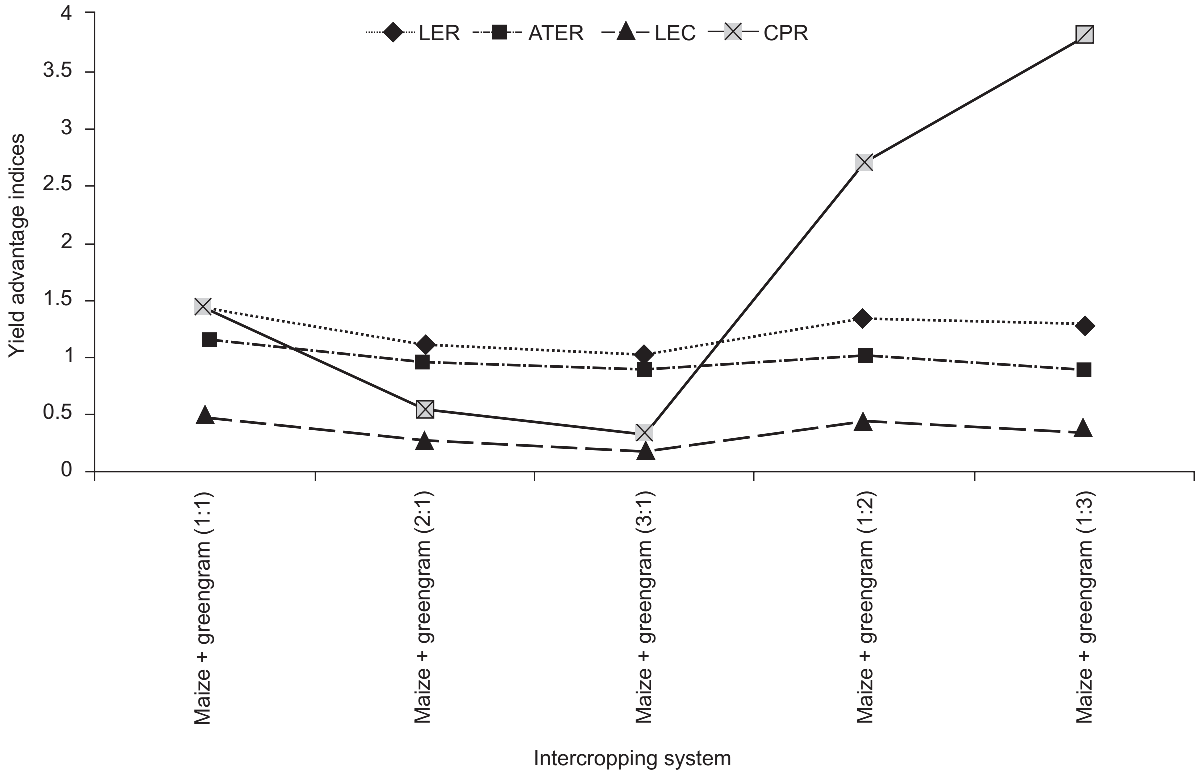

Fig 1 Effect of maize + greengram intercropping system onyield advantage indices

This might be due to less competition for moisture, nutrient and sunlight for both the crops under the above mention treatment. Moreover, better performance of MEY in case of treatment T_3 might be due to bonus yield of greengram in the cropping system (T_3) without utilizing additional space for the said crop.The same trend of results was also recorded in case of LER, ATER, LEC (Fig 1) and MAI (Table 3). The treatment T_3 recorded the highest LER (1.43), ATER (1.19), LEC (0.49) and MAI (₹ 3 273) which was closely followed by T_6 (i.e. 1.34, 1.01, 0.44 and ₹ 2 684, respectively) over all the intercropping system. However, the highest CPR was recorded in the treatment T_7 (3.81) which was closely followed by T_6 (2.69) over other intercropping system (Fig 1). This might be due to spatial arrangement of individual crop in the intercropping system. This result is in conformity with the findings of Singh *et al.* (2011).

Economics

The highest net return was recorded in the intercropping system T_3 ₹ 47.1 × 10^3 at the cost of cultivation ₹ 20.6 × 10^3. This same treatment gave highest B:C ratio 3.28 and crop profitability ₹ 496 ha/day. However, this treatment was closely followed by T_6 recorded net returns of an amount of ₹ 42.3 × 10^3, B: C ratio 3.09 and crop profitability ₹ 445.1 ha/day (Table 4). This result is in conformity with the findings of Kachhadiya *et al.* (2009).The higher MEY coupled with the corresponding stover yield in the treatment T_3 and T_6 with minimal increases in cost of cultivation has resulted in higher net returns and B: C ratio in maize and green gram system. Both the treatment T_3 and T_6 increased mean net returns by 40.0, 31.2% and 33.2, 23.3% over sole cropping of maize and green gram, respectively. Similar results were reported by (Ansari *et al.* 2012).

Table 4 Effect of intercropping system on economics

Treatment	Economics				Crop profitability (₹/ha/day)
	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	
Sole maize	18 130	46 377	28 247	2.56	235.4
Sole greengram	16 270	48 685	32 415	2.99	463.1
Maize + greengram (1:1)	20 630	67 754	47 124	3.28	496.0
Maize + greengram (2:1)	19 530	50 263	30 733	2.57	323.5
Maize + greengram (3:1)	19 130	46 574	27 444	2.43	288.9
Maize + greengram (1:2)	20 200	62 480	42 280	3.09	445.1
Maize + greengram (1:3)	19 180	59 370	40 190	3.10	423.1

Table 5 Effect of intercropping systems on energy budgeting

Treatment	Energy budgeting				
	Input energy (× 000 MJ/ha)	Output energy (× 000 MJ/ha)	Net energy (MJ/ha)	Energy efficiency	Energy productivity (g/MJ)
Sole maize	9.8	199.5	189.7	20.4	1713.0
Sole greengram	4.8	49.3	44.4	10.1	678.6
Maize + greengram (1:1)	10.3	196.6	186.3	19.1	1569.4
Maize + greengram (2:1)	10.2	147.5	137.3	14.5	1172.0
Maize + greengram (3:1)	10.2	158.0	147.8	15.5	1273.5
Maize + greengram (1:2)	10.2	128.1	117.9	12.6	991.5
Maize + greengram (1:3)	10.2	103.3	93.1	10.1	785.6

Energy budgeting

The input energy differences were due to the energy value under different row proportions. The highest output energy was recorded under sole maize closely followed by maize + greengram (1:1) than others. However, it is dependent on grain and stover/straw yields under different treatments and higher yields registered greater output energy. Hence energy efficiency (output: input ratio) and energy productivity per unit of energy used (in MJ) may be considered for energy relationships. Besides maize sole cropping, among different row proportions, 1:1 row ratio recorded maximum energy efficiency (19.1) and energy productivity (1 569.4 g/MJ), than other intercropping system. This may be due to higher energy production under the said system. These results are in close agreement with those of Ghosh *et al.* (2009) and Singh *et al.* (2011).

Thus results of the present investigation clearly demonstrate that maize/greengram intercropping system in 1:1 or 1: 2 row ratios can be practiced to achieve better land utilization, high yield as well as profitability and energy efficiency than their sole crop under rainfed sandy loam soils.The risk of low yields or crop failure associated with the prevailing traditional monoculture production system under rainfed condition of eastern Himalayan region could be reduced through changing in cropping pattern and management practices.

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