



Performance of maize (*Zea mays*) varieties in different cropping geometry with greengram (*Vigna radiata*)

L K BAISHYA^{1*}, Z KAWIKHONLIU¹, MERYANI M LOTH¹ and D J RAJKHOWA¹

ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema, Nagaland 797 106, India

Received: 16 August 2022; Accepted: 19 October 2022

ABSTRACT

An experiment was conducted at the ICAR Nagaland Centre during rainy (*kharif*) season of 2018–2019 and 2019–2020 to check the most suitable maize (*Zea mays* L.) variety and cropping geometry for maize + greengram (*Vigna radiata* L.) intercropping system. The results revealed that among the varieties of maize, VHM-45 recorded highest grain yield (4.92 t/ha) and stover yield (14.76 t/ha). Whereas, in intercropping system 1:1 (maize + greengram) recorded highest grain yield (5.16 t/ha) and stover yield (17.06 t/ha). The highest grain yield (1.27 t/ha) and stover yield (2.64 t/ha) of greengram was recorded in sole crop. Maize equivalent yield (MEY) was highest in VHM-45 intercropped with greengram (8.73 t/ha). Whereas, in crop geometry, maize + greengram (1:1) intercropping system recorded the highest MEY (9.16 t/ha). The soil nutrient status after harvest showed an increase in available N, P₂O₅ and K₂O kg/ha in sole or higher density in greengram as compared to others. The competition functions like land equivalent ratio (LER) and aggressivity (A) in maize + greengram prominently indicated benefits of the intercropping system. Similarly, highest profitability and energy efficiency was recorded in VHM-45 among the maize varieties and among the cropping geometry; additive series (maize + greengram 1:1) recorded the highest profitability and energy profitability respectively.

Keywords: Energy, Intercropping, Maize equivalent yield, Maize varieties

The ever expanding population of the world and the shrinking of the agricultural land is an evidence that there is a huge challenge to meet the demand of the basic necessities like food, fuel for human consumption and fodder for animals. Increasing the production through traditional agriculture, i.e. expanding the cultivated area stands no chance in overcoming the challenges. Increase in food production and adoption of modern farming may be the temporal way. It includes adoption of modern varieties, practicing improved cultural techniques and maintaining the proper cropping system especially in eastern Himalayan Region.

Intercropping was found to be a beneficial system of crop production in semi-arid tropics with substantial yield advantage compared to sole cropping. Intercropping also ensures effective and efficient utilization of available resources, viz. nutrients and water, better interception of solar radiation, risks reduction from adverse climatic condition. Intercropping system, particularly cereal + legume intercropping improves the soil health (Sanginga and Woormer 2009) as well as the yield of the main crop (Beedy

et al. 2010). It also plays vital role in sustainable agriculture as it provides diversified food crops in both developed and developing countries particularly, in areas with irrigation water as limiting factor (Tsubo *et al.* 2005). Maize (*Zea mays* L.) being the third most important cereal crop in the world requires special attention, hence, adoption of the modern varieties and recognizing the potentials of those varieties in the particular agro-climatic condition is the need of the time. Maize is one of the most suitable crops for intercropping as its inter-row spaces can be utilized for legumes in the interspaces. Maize+legume intercropping was found to yield more and have lesser risk than the maize-legume rotation (Kamanga *et al.* 2010). Therefore, the present study was carried out to find the most suitable maize varieties and cropping geometry for maize + greengram (*Vigna radiata* L.) intercropping system.

MATERIALS AND METHODS

The present study was carried out at Research farm of ICAR Research complex for North Eastern Hill Region (NEHR), Nagaland Centre, (26.1584° N and 94.5624° E with a mean altitude of 290 m amsl) Medziphema during rainy (*kharif*) season of 2018–2019 and 2019–2020. The soil texture of the farm is silty loam and initial soil test values exhibited acidic (pH 5.1), low in organic carbon (0.4%),

¹ICAR Research Complex for NEH Region, Nagaland Centre, Nagaland. *Corresponding author email: lkbicar@gmail.com

medium in available nitrogen (160 kg/ha), available P_2O_5 (12.5 kg/ha), and available K_2O (210 kg/ha). The average maximum temperature recorded were 33.5°C in 2019 and 32.4°C in 2020 and the minimum temperature recorded were 14.3°C in 2019 and 14.1°C in 2020 respectively, maximum relative humidity of 94% was recorded both in the year 2019 and 2020 and minimum relative humidity of 46% in the year 2019 and 41% in the year 2020 respectively. A total rainfall of 160.92 mm was recorded during 2019 and 155.34 mm in 2020 (Fig 1).

The experiment was laid out in Factorial RBD with three replications. Treatment consisted of 4 varieties of maize, viz. V_1 , RCM-76 + greengram; V_2 , RCM-75 + greengram; V_3 , RCM-1-2 + greengram and V_4 , VMH-45 + greengram, which were tested with five cropping geometry, viz. G_1 , sole greengram in spacing of 30 cm × 10 cm to achieve plant population of 333.3×10^3 /ha; G_2 , 1:1 (one row maize and one row greengram, additive series) 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; G_3 , 1:2 (one row maize and two row greengram, replacement series) to maintain plant density for maize 50×10^3 /ha and 33.3×10^3 /ha (60 cm × 10 cm) for greengram; G_4 , 2:1 (two row maize and one row greengram, replacement series) to maintain plant density for maize 66.6×10^3 /ha and 66.6×10^3 /ha (60 cm × 10 cm) for greengram; G_5 , 2:2 (two row maize two row greengram, replacement series) to maintain plant density for maize 66.6×10^3 /ha and 133.3×10^3 /ha for greengram. The fertilizer schedule was 80:60:40 kg N:P₂O₅:K₂O/ha for sole as well as intercropped maize without additional nutrient to intercrop. The economic yield of sole greengram and intercrop greengram was converted into maize equivalent yield (MEY) based on the minimum support price (MSP).

The soil samples were collected at a depth of 15 cm, dried and sieved through 2 mm sieve. The soil pH was determined in 1:2.5 soil water suspensions; using glass electrode pH meter. Organic carbon of the soil was estimated by Walkley and Black method. The available nitrogen, phosphorus and potassium content of the soil was determined by ordinary distillation method using alkaline potassium permanganate method, Bray and Kurtz No. 1 method using 0.03 N NH_4F in 0.025 N HCl and neutral ammonium acetate, determined using flame photometer respectively. The index of agronomic yield advantage like Land Equivalent Ratio (LER) was calculated by $LER = Y_{ab}/Y_{aa} + Y_{ba}/Y_{bb}$. Where, Y_{aa} , yield of component as a sole crop; Y_{bb} , yield of component b as a sole crop; Y_{ab} , yield of component a as intercrop grown in combination with component b and Y_{ba} , yield of component b as intercrop grown in combination with component a.

The aggressivity (A) of the crop was calculated as:

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Where, A_{ab} , aggressivity of 'a' in the mixture over 'b'; Y_{aa} , yield of component crop 'a' as sole crop; Y_{bb} , yield of component crop 'b' as sole crop; Y_{ab} , yield of component crop 'a' as intercrop in combination with 'b'; Y_{ba} , yield of component crop 'b' as intercrop in combination with 'a'; Z_{ba} , sown proportion of component b in combination with 'a'; Z_{ab} , sown proportion of component a in combination with 'b'. Calculation of LER and aggressivity of the average yield of the maize varieties was considered as a sole crop yield. Economics of different treatment combinations was worked out by considering the cost of inputs and income obtained from output (grain and stover yield) as:

Net return = Gross return – Cost,

Benefit:cost = Gross return/cost of cultivation

The system production efficiency (kg/ha/day) and energy indices were calculated as:

Energy efficiency = Total energy output (MJ/ha)/Total energy input (MJ/ha)

Energy Productivity = Output (grain + by-product) (kg/ha)/Total energy input (MJ/ha)

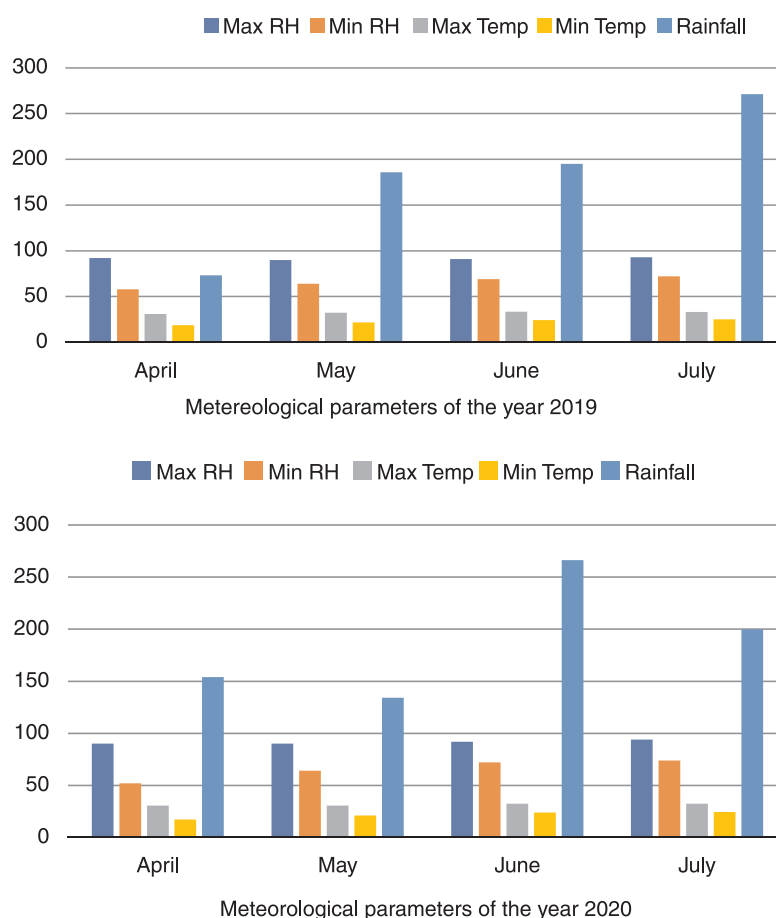


Fig 1 Graphical representation of the meteorological parameters of the cropping season 2019 and 2020.

Net energy = Energy output (MJ/ha)/Energy Input (MJ/ha).

The resource inputs and outputs converted from physical to energy unit (MJ) through various published conversion coefficients were calculated using the following indicators by Kumar *et al.* (2019).

RESULTS AND DISCUSSION

Growth, yield and yield attributes

Maize: The yield and yield attributes of different varieties of maize were significantly influenced by maize + greengram intercropping system (Table 1). Stem girth (4.91 cm), cob/plant (1.60) and seeds/row (42.95) were significantly highest in RCM-76 which was found to be at par with VMH-45. The result also revealed that highest grain yield (4.92 t/ha) and straw yield (14.76 t/ha) was recorded in VMH-45 maize. The higher yield of VMH-45 is due to superiority in all the yield attributes and the lower grain yield in other varieties might be due to lower yield attributes. This result corroborates with the findings of Alom *et al.* (2009).

Among the different intercropping system, highest maize grain yield (5.16 t/ha) and stover yield (15.48 t/ha) was recorded in 1:1 maize + greengram crop geometry followed by 4.59 t/ha (tonnes/hectare) grain yield in 2:1 (maize + greengram) cropping geometry (Table 1). However, highest plant height (222.38 cm) and cob length (23.75 cm) was recorded significantly in 1:2 crop geometry. Grain yield advantage of maize in 1:1 maize + greengram arrangement might have resulted from temporal and spatial complementarities as compared to other arrangement, which corroborated with the findings of Khoroar and Patra (2014).

Greengram: The result revealed that different varieties of maize did not significantly influenced the yield of the greengram (Table 1). However, greengram intercropped with RCM-76 recorded highest plant height (88.45 cm) and longest pod length (6.88 cm) whereas significantly highest number of pod/plant (27.71) was recorded in greengram intercropped with RCM-75.

Studies on the influence of crop geometry on yield and yield attributes of greengram revealed that sole cropping recorded highest plant height (89.45 cm), and number of branches (3.47). Whereas, significantly highest pod/plant (27.69), pod length (6.98 cm) and seeds/pod (11.56) were recorded in 1:1 (maize + greengram) intercropping system. The stover yield (2.64 t/ha) and the grain yield (1.27 t/ha) of greengram were significantly highest in sole crop, followed by (0.96 t/ha) 1:1 (maize + greengram) crop geometry. The reason for the inferior performance of the greengram intercropped with maize as compared to sole cropping could be probably due to lower utilization of the percentage of incoming solar radiation. Similar result was reported by Khoroar and Patra (2014) and Tohura *et al.* (2014).

Maize equivalent yield: The performance of the intercropped maize and greengram was evaluated on basis of maize equivalent yield by converting the yield of the respective crop into maize equivalent yield (MEY). The

Table 1 Yield attributes and yield of maize varieties and greengram in maize + greengram intercropping system

Treatment	Plant height (cm)	No. of green leaves	Stem girth (cm)	Plant stand Maize	Cob per plant	Cob length (cm)	Row per cob	Seed per row	Stover yield (t/ha)	Grain yield (t/ha)	Plant height (cm)	No. of branches	Pod per plant	Pod length (cm)	Seed per pod	Stover yield (t/ha)	Grain yield (t/ha)
Maize																	
V ₁	218.14	12.18	4.91	83.00	1.60	23.53	12.52	42.95	12.03	4.01	88.45	3.23	27.24	6.88	11.46	2.59	0.96
V ₂	217.45	11.75	4.86	79.31	1.38	23.53	12.91	40.79	12.33	4.11	86.31	3.09	27.71	6.54	11.13	2.45	0.96
V ₃	218.20	11.94	4.57	79.46	1.39	23.55	12.73	40.56	13.64	4.55	83.87	3.15	27.25	6.54	11.28	2.41	0.88
V ₄	215.71	12.06	4.87	79.56	1.40	23.92	12.64	42.05	14.76	4.92	82.61	3.06	25.15	6.77	11.27	2.44	0.92
SE(m)±	2.27	0.07	0.07	2.20	0.03	0.31	0.12	0.55	0.10	0.03	1.04	0.06	0.23	0.06	0.13	0.05	0.02
CD (P=0.05)	NS	NS	0.20	NS	0.09	NS	NS	1.58	0.27	0.09	2.98	NS	0.62	0.18	NS	NS	NS
Greengram																	
G ₁	219.46	12.07	4.74	79.24	1.45	23.73	13.01	42.24	15.48	5.16	89.45	3.47	26.55	6.98	11.30	2.64	1.27
G ₂	222.38	11.89	4.82	75.18	1.45	23.75	12.49	40.99	10.25	2.01	82.85	3.21	27.69	6.69	11.56	2.43	0.97
G ₃	221.71	12.01	4.78	74.24	1.45	23.68	12.75	40.24	12.86	4.59	87.09	3.06	26.46	6.57	11.00	2.35	1.17
G ₄	210.18	11.99	4.76	79.93	1.39	22.42	12.74	42.32	10.31	3.6	85.80	3.01	26.15	6.66	11.51	2.49	0.81
G ₅	254	0.07	0.08	2.46	0.03	0.35	0.14	0.62	0.11	0.04	1.16	0.07	0.24	0.07	0.14	0.05	0.02
SE(m)±	7.292	NS	NS	7.07	NS	1	NS	NS	0.30	0.1	3.34	0.21	0.70	0.20	0.40	0.15	0.07
CD (P=0.05)																	

Treatment details given under Materials and Methods.

Table 2 Maize equivalent yield (MEY), land equivalent ratio (LER), aggressivity, economics and soil nutrient status after harvest of maize + greengram intercropping system

Treatment	Maize equivalent yield	LER of system	Aggressivity of maize	Aggressivity of greengram	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C	Profitability (₹/ha/day)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
V ₁	7.93	1.67	-	-	31058	146720.2	115662.2	4.72	963.85	271.27	13.81	169.87
V ₂	8.04	1.69	-	-	31058	148719.5	117661.5	4.79	980.51	269.91	13.77	170.47
V ₃	8.19	1.73	-	-	31058	151477.6	120419.6	4.88	1003.5	270.43	14.1	171.41
V ₄	8.73	1.84	-	-	34808	161452	126644	4.64	1055.37	267.66	13.95	170.8
SE(m) ±	-	-	-	-	-	-	-	-	-	11.88	0.42	6.35
CD (P=0.05)	-	-	-	-	-	-	-	-	-	NS	NS	NS
<i>Crop geometry</i>												
G ₁	4.98	-	-	-	24405	92049.95	67644.95	3.77	563.71	286.92	15.22	182.72
G ₂	9.16	1.93	0.41	-0.41	30945	169469.1	138524.1	5.48	1154.37	251.23	12.86	173.48
G ₃	6.73	1.38	-0.01	0.01	30300	124528.2	94228.2	4.11	785.24	276.93	14.47	177.13
G ₄	7.14	1.52	0.14	-0.14	29295	132096.7	102801.7	4.51	856.68	272.5	13.47	165.72
G ₅	6.92	1.46	0.36	-0.36	28695	128086.6	99391.6	4.46	828.26	261.49	13.51	154.25
SE(m) ±	-	-	-	-	-	-	-	-	-	13.29	0.47	14.19
CD (P=0.05)	--	-	-	-	-	-	-	-	-	NS	1.36	NS

* Average yield of all the maize variety was considered as sole crop yield of maize for calculating LER and aggressivity. Treatment details given under Materials and Methods.

data (Table 2) revealed that the equivalent yield of maize and greengram was influenced markedly in response to their different varieties of maize and crop geometry. Among the varieties, VHM-45 intercropped with greengram recorded the highest maize equivalent yield (8.73 t/ha) followed by RCM-1-2 (8.19 t/ha). Higher maize equivalent yield in varieties may be particularly due to the higher yielding capacity of the varieties. Among the different crop geometry, the additive series 1:1 (maize + greengram) intercropping system recorded highest maize equivalent yield of 9.16 t/ha which was 83.94% higher than the sole crop greengram. However, among all the row combination of the replacement series, the highest maize equivalent yield was recorded by 2:1 (maize + greengram) which is 43.37% higher than the sole crop greengram but every row combination of replacement series performed about 30% better than sole crop greengram in terms of maize equivalent yield, and the same was reported by Baishya *et al.* (2021). Advantages on maize equivalent yield of intercropping over their respective monoculture could be due to combined yield of the both crop.

Land equivalent ratio: Studies on land equivalent ratio (Table 2) revealed that among different maize varieties, VMH-45 intercropped with greengram recorded highest LER with the value 1.84. Whereas, among the different crop geometry, the highest LER (1.93) was recorded in maize + greengram (1:1) intercropping system and the lowest LER (1.38) was recorded in 1:2 (maize + greengram) crop geometry. The recorded value of LER in all the intercropping system is more than one (1.00) which indicates a total yield advantage of growing of intercrop over sole. The cited advantage might be due to maximum complementary use of different growth resources in intercropping system (Alom *et al.* 2009, Manasa *et al.* 2018).

Aggressivity: The study on the aggressivity of the cropping system as influenced by cropping geometry revealed that in all the different cropping geometry, component crop, i.e. maize is dominant over greengram, except in 1:2 cropping geometry where greengram is dominant over maize. Maize being a C₄ plant, is more competitive and more aggressive in terms of utilization of available resources as compared to intercrops (greengram). The results also revealed that 1:1 cropping geometry recorded the highest value (0.41) of aggressivity which means greater the value, bigger is the difference in competitive abilities and bigger the difference between actual and expected yields. On the other hand, 1:2 (maize + greengram) intercropping system recorded the least value of aggressivity (0.01) with greengram being the dominant crop. Similar results were reported by Khoroar and Patra (2014) and Manasa *et al.* (2018).

Economics: The economics of different varieties and cropping geometry (Table 2) revealed that among the varieties, VMH-45 intercropped with greengram recorded highest gross return of ₹161452.00 and net return of ₹126644.00 at the cost of cultivation ₹34808.00. This same treatment recorded highest crop profitability (₹1055.37 kg/ha/day). However, the highest B:C ratio was recorded in RCM-1-2 (4.88). Among the cropping geometry, (additive

Table 3 Energy budgeting on maize + greengram intercropping system

Treatment	Input energy ($\times 10^3$ MJ/ha)	Output energy ($\times 10^3$ MJ/ha)	Energy efficiency	Energy productivity (g/MJ)	Net energy ($\times 10^3$ MJ/ha)
<i>Varieties</i>					
V ₁	10.20	116.58	11.43	777.53	106.38
V ₂	10.20	118.17	11.59	788.13	107.97
V ₃	10.20	120.36	11.80	802.74	110.16
V ₄	10.20	128.29	12.58	855.60	118.09
<i>Crop geometry</i>					
G ₁	7.90	73.14	9.26	629.83	65.24
G ₂	10.30	134.66	13.07	889.37	124.36
G ₃	10.20	98.95	9.70	659.93	88.75
G ₄	10.20	104.96	10.29	700.04	94.76
G ₅	10.20	101.78	9.98	678.78	91.58

*Energy value considered as, Labour (1 h) = 1.96 MJ; Diesel fuel (1 litre) = 47.87 MJ; Nitrogen (N/kg) = 60.60 MJ; Phosphorus (P₂O₅) (kg) = 11.10 MJ; Potassium (K₂O/kg) = 6.70 MJ (Singh and Mittal 1992); Maize/greengram (kg) = 14.70 MJ; Stover (kg) = 12.5 MJ (Singh and Mittal 1992). Treatment details given under Materials and Methods.

series) maize + greengram (1:1) was found to be most profitable with the cost of cultivation ₹30954.00, gross return of ₹169469.11, net return of ₹138524.11, B:C ratio (5.48) and system profitability of 1154.37 g/MJ. The result is in close conformity with the findings of Baishya *et al.* (2014). The profitability of the particular cropping geometry may be due to the higher MEY of the treatment with minimal increase in cost of cultivation.

Available soil nutrient status: The available nutrient status of the soil after harvest is presented in Table 2. The perusal of the data shows that effect of different varieties of maize on available nitrogen, available phosphorus and available potassium did not show any significant differences due to the varieties. Available nitrogen and available potassium due to different cropping geometry were found to be non-significant. However, available phosphorus was found to be significantly highest (15.22 kg/ha) in sole greengram which was found to be at par with 1:2 maize + greengram cropping geometry (14.7 kg/ha). The pulse crop secrete greater amount of acid phosphatase from roots to the soil than maize which helps to improve the overall soil health by increasing the total available phosphorus in the soil. The result was in conformity with the finding of Patel *et al.* (2017)

Energy budgeting: The evaluation of energy budget for different maize varieties and cropping geometry of maize + greengram intercropping system (Table 3) revealed that in maize varieties, highest output energy (128.29 MJ/ha), energy efficiency (12.58) and energy productivity of 0.86 g/MJ was recorded in VMH-45 + greengram. Whereas, among the cropping geometry of maize + greengram intercropping system, additive series (maize + greengram, 1:1) recorded highest input energy (10.30 MJ/ha), net output energy (134.66 MJ/ha), energy efficiency (13.07) and energy productivity of 889.37 g/MJ. The result was in line with the findings of Baishya *et al.* (2014, 2021).

The result of the experiment can be summarized with the fact that VHM-45 performed best in maize + greengram intercropping system. The crop geometry reveals that 1:1 (maize + greengram) cropping ratio is the promising ratio as competition functions like land equivalent ratio (LER) and aggressivity (A) prominently indicated the benefits of maize + greengram intercropping system. The soil fertility status was found to improve with the inclusion of higher density of greengram as compared to 1:1 (maize + greengram) cropping ratio. The economic and energy budgeting recorded that the growing of RCM-1-2 and intercropping of maize + greengram in additive series of 1:1 was found to be most profitable for better benefit:cost ratio.

REFERENCES

- Alom M S, Paul N K and Quayyuma M A. 2009. Performances of different hybrid maize (*Zea mays* L.) varieties under intercropping systems with groundnut (*Arachis hypogaea* L.). *Bangladesh Journal of Agricultural Research* **34**(4): 585–95.
- Baishya L K, Ansari M A, Walling I, Sarma P K and Prakash N. 2014. Productivity, profitability and energy budgeting of maize (*Zea mays*)/greengram (*Vigna radiata*) intercropping system under rainfed conditions of Eastern Himalaya Region. *Indian Journal of Agricultural Sciences* **84**(9): 1073–77.
- Baishya L K, Jamir T, Walling N and Rajkhowa D J. 2021. Evaluation of maize (*Zea mays* L.) + legume intercropping system for productivity, profitability, energy budgeting and soil health in Hill terraces of Eastern Himalayan Region. *Legume Research* **44**(11): 1343–47.
- Beedy T L, Snapp S S, Akinnifesi F K and Sileshi G W. 2010. Impact of *Gliricidia sepium* intercropping on soil organic matter fractions in a maize based cropping system. *Agriculture, Ecosystems and Environment* **138**(3/4): 139–46.
- Kamanga B C G, Wadding S R, Robertson M J and Giller K E. 2010. Risk analysis of maize-legume crop combination with smallholder farmers varying in resource endowment in central Malawi. *Experimental Agriculture* **46**(1): 1–21.
- Kheroar S and Patra B C. 2014. Productivity of maize-legume

- intercropping systems under rainfed situation. *African Journal of Agricultural Research* **9**(20): 1610–17.
- Kumar S, Gautam R K and Dey A. 2019. Energy budgeting of crop- livestock- poultry integrated farming system in irrigated ecologies of eastern India. *Indian Journal of Agricultural Sciences* **89**(6): 1017–22.
- Manasa P, Maitra S and Reddy M D. 2018. Effect of summer maize-legume intercropping system on growth, productivity and competitive ability of crops. *International Journal of Management, Technology And Engineering* **8**(XII): 2249–7455.
- Patel A K, Ardeshta R B and Kumar D. 2017. Quality characters of maize and NPK status of soil as influence by various sole and intercropping treatments. *International Journal of Current Microbiology and Applied Sciences* **6**(9): 1558–65.
- Singh S and Mittal J P. 1992. *Energy in Production Agriculture*, pp. 6–12. Mittal publications, New Delhi, India.
- Tohura T, Ali M S, Rahman M M, Chowdhury I F and Mony F T Z. 2014. Yield performance of mungbean maize intercropping grown under different planting geometry. *International Journal of Agricultural Technology* **10**(9): 22–27.
- Tsubo M, Walker S and Ogindo H O. 2005. A simulation model of cereal–legume intercropping systems for semi-arid regions: I. Model development. *Field Crop Research* **93**: 10–22.