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Production Potential, and Energetic Studies as Affected by Pigeon pea (*Cajanus cajan* L.) and Finger millet (*Eleusine coracana* L.) Intercropping System

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A B S T R A C T

Pigeon pea (*Cajanus cajan* L.) is grown in rainfed as well as dry region of India, growing of only pulses is not so much remunerative in present scenario of dry areas of agriculture to fulfill the diverse demand of consumers and rapid growing population. A field experiments was conducted during the *Kharif* seasons of 2005 and 2006 at Birsa Agricultural University Farm, Ranchi, Jharkhand to assess the energetics and production potential of pigeon pea (*Cajanus cajan* L.) in sole and intercropping with different duration (short, medium, and long) cultivars of finger millet under 1:1, 1:2, 1:3 and 1:4 row proportions. Sole crops of pigeon pea and finger millet always showed highest yield attributes that decreased due to intercropping with different duration cultivars of finger millet and number of rows of finger millet. Pods plant^{-1}, seeds pod^{-1} and 100 seed weight of pigeon pea and ears m^{-1} row length, seeds ear^{-1} and test weight of finger millet were recorded higher under pigeon pea and finger millet intercropping system in 1:1 row ratio and reduced in 1:4 row ratio. The maximum grain yield 10.9qha^{-1} was obtained with pigeon pea sole which was significantly superior to intercropping systems. Grain yield of pigeon pea increased with decreased in row ratio of finger millet and grain yield of finger millet increased when row ratio of finger millet increased. The maximum pigeon pea equivalent yield i.e. 13.13 qha^{-1}, net returns (Rs. 15090.5 ha-1) and benefit: cost ratio (2:31) was recorded when pigeon pea intercropped with finger millet in 1: 1 row combination with short duration cultivars of finger millet. When row ratio of finger millet increased energy use efficiency and net energy output of biomass increased and specific energy was decreased irrespective of all the cultivars.

Introduction

Intercropping is a potentially beneficial system, shows substantial yield advantage over sole cropping and reduces risk. This advantage can be achieved not by means of costly inputs but by simple expedient of growing crops together (Willey, 1979). Intercropping especially cereal with legume combination can increase production and productivity by better utilization of resources and there by minimizes the risks and brings stability under rainfed conditions. Finger millet is an important coarse cereal of tropical

climate, grown mostly under rainfed and short drought spell situation in poor and marginal soils of hill as well as arid and semi-arid region of the country. Finger millet has strong compensatory ability in terms of tiller production.

The adjustment ability of finger millet crop under wide range of row spacing and plant population makes it a suitable choice of intercropping with pigeon pea. An improved short and medium duration finger millet cultivars in place of long duration finger millet which can give more yield, will be an ideal option of intercropping with pigeon pea. Being a short duration crop, its timely sowing and early harvesting it may ensure sufficient residual moisture in the soil which can be well utilized by the companion crop with dissimilar rooting system as well as canopy structure.

With the development of Indian Agriculture, crop production and rural agro-processing has emerged as one of the major consumer of commercial energy. In recent day of energy crisis, a crop scientist aims to harvest maximum energy from crop in a cropping system with minimum energy requirement. Energy input increases with increase in cropping intensity and it varies with the nature of component crops. Higher energy requirement of cereals than grain legumes/oilseeds is due to mainly to higher requirement of nutrient, water and physical energy animal, manual and efficiently per unit area per unit time there by produces more energy per unit of energy input (Verma *et al.*, 1994).

Crop production directly related to the optimum use management of energy inputs (seed, fertilizer, irrigation, labours etc.) to increase productivity. The cost of these inputs are increasing day by day. Therefor energetics analysis has become an important aspect for planting of crop production system.

Materials and Methods

A field experiments was conducted during two consecutive kharif season of 2005 and 2006 at Birsa Agricultural University Farm, Ranchi, Jharkhand to study the effect of different row ratio and cultivars of finger millet on productivity and economics. The experimental soil was sandy loam having pH 5.55, low in available N (190.2 kg ha $^{-1}$) and P (10.65 kg ha $^{-1}$) and medium in available K (145.0 kg ha^{-1}). The sixteen treatments consisted of pigeon pea BR-65 (180-200 days duration) as base crop and three cultivars of finger millet short duration (SD) Birsa Marua -1 (85-95 days duration), medium duration (MD) HR-374 (105-115 days duration) and long duration (LD) PR-202 (120-130 days duration) taken as sole as well as intercrops in four row ratios (1:1,1:2, 1:3 and 1:4) were laid out in RBD with three replications. In pigeon pea sole full dose of fertilizers (25-22.0-20.8 kg N-P-K ha^{-1}) was applied at the time of sowing. While Sole crop of finger millet and pigeon pea + finger millet intercropping system, 25 kg additional N was applied 30 days after sowing. Two weeding were done at 15 and 30 days after sowing. At the time of sowing, 0.3 t ha^{-1} of lime was applied in furrows of pigeon pea to neutralized local zone pH of the soil. Crops were sown in 1st week of July in both the year of experimentation. During crop period from July to December about 830.5mm and 1292.9mm rainfall were received in 2005 and 2006, respectively. Pigeon pea equivalent yield was worked out by converting the yields of intercrops to the yield of pigeon pea on the basis of prevailing market price of each crop. The economics of different crops and crop combinations were computed on the basis of prevailing market rates of produce and agro inputs. Energy input of each treatment was calculated from recorded data for each component of operations as expressed in Mega Jule (MJ) / ha taking standard values suggested by Panesar and Bhatnagar (1994).

Similarly, energy output by grain and straw yield (kg/ha) of each treatment was also converted into energy unit. The energy - use efficiency based on output; input energy ratio was determined to assess the efficiency of nutrient management practices. Specific energy MJq-1) was calculated by dividing input energy by the corresponding grain equivalent yield.

Results and Discussion

Yield attributes

Sole crops of pigeon pea and finger millet always showed highest yield attributes that decreased due to intercropping with different duration cultivars of finger millet and number of rows of finger millet (Table 1). Pods plant^{-1}, seeds pod^{-1} and 100 seed weight of pigeon pea were recorded maximum under sole condition. In intercropping systems, maximum yield attributes were recorded under pigeon pea + finger millet (SD) 1:1 row ratio and the lowest value in long duration finger millet at 1: 4 ratio. It might be due to varying competition between component crop for light, moisture, nutrient and space with increase in plant density. More reduction in yield attribute of pigeon pea were found when it was intercropped with long duration finger millet and less with medium and short duration finger millet cultivars. This may be attributed to smothering and more competitive effect of long duration finger millet for longer period of pigeon pea.

The yield attributes of finger millet like ears m^{-1} row, seeds ear^{-1} and test weight were reduced by 14.7, 23.1,and 4.6 per cent in Long duration,22.77,18.36 and 1.28 in Medium duration and 21.31, 16.29 and 2.25 per cent in Short duration cultivars, respectively in intercropping with pigeon pea under 1:4 row proportion. This was due to intense competitative effect of greater population pressure of finger millet on lesser population of pigeon pea. Non-significant reduction in yield attributing characters of finger millet in short, medium and long duration cultivars was observed due to less shading effect of pigeon pea. Similar findings were also reported by Maitra *et al.,* (2000).

Grain and stalk/ straw yield

The maximum grain and stalk/ straw yield of pigeon pea and finger millet was recorded under sole cropping when compared to intercropping systems (Table 2). Under intercropping system, maximum grain and stalk yield of pigeon pea was obtained under pigeon pea + finger millet (short duration) 1:1 row ratio followed by pigeon pea + finger millet (medium duration) 1:1 row ratio as compared to other row combinations. It may be due to wider spacing of intercrop compared to other row arrangement facilitating effective sharing of growth resources with finger millet to get higher grain yield. Among finger millet cultivars, intercropping of short duration cultivars produced higher grain and stalk yield of pigeon pea irrespective of row proportion. It may be due to minimum competition between pigeon pea with short duration cultivar of finger millet at initial growth period. Short duration finger millet is fast growing as compared to pigeon pea. At 90 days of crop growth, pigeon pea attainded their reproductive period and at this period short duration finger millet attended their harvesting stage. Therefore, no competition between pigeon pea and short duration finger millet at reproductive period and that was the reason for higher yield. While the long duration cultivar of finger millet recorded the higher grain and straw yield irrespective of row proportion as they get more time to complete their life cycle facilitating better vegetative growth and mobilization of assimilates source to sink. It was interesting to note that when row ratio of finger millet

increased in pigeon pea + finger millet intercropping system, yield of finger millet increased due to higher plant densities and yield of pigeon pea was decreased due to competition effect of higher plant densities of finger millet. This is in conformity with the findings of Mahto *et al.,* (2007) who reported that intercropping with decreased plant density of finger millet in association with pigeon pea resulted in higher grain yield of pigeon pea.

Pigeon pea equivalent yield

Data recorded on pigeon pea equivalent yield revealed that pigeon pea in association with finger millet recorded maximum pigeon pea equivalent yield with pigeon pea + finger millet (SD) 1:1 (13.13 q ha^{-1}) row proportion followed by pigeon pea + finger millet (MD) 1:1(12.92 q ha^{-1}) row proportion may be due to higher yield of pigeon pea and higher value of pigeon pea in alternate row intercropping system (Table 2). Higher pigeon pea equivalent yield in intercropping system may be attributed to slow growing habit and temporal differences between the pigeon pea and finger millet intercrop, difference in growth habit and rooting pattern made both crops suitable for intercropping in alternate row system. Similar finding was also observed by Kumar *et al.,* (2009) in Pigeon pea + little millet intercropping system. The short duration finger millet due to initial better growth, suffered less competition from pigeon pea. While long duration finger millet in 1:1 row proportion recorded comparatively lower yield as part of its grand growth coincided with the grand growth period of pigeon pea which adversely affected the growth and development of associated pigeon pea. Intercropping of pigeon pea with finger millet in 1:4 row proportion in all the three cultivars of long, medium and short duration of finger millet gave lower pigeon pea equivalent yield (10.23-LD, 9.39-MD and 9.33 qha-1-SD) compared to sole crop of pigeon pea (10.9 qha-1) owing to more interspecies competition of component crops, resulting in reduction in pigeon pea yield.

Economic

Pigeon pea+ finger millet (SD) 1:1 row proportion produced maximum net returns (Rs. 15090.5 ha^{-1}) and Benefit : cost ratio (2:31) which was comparable to pigeon pea + finger millet (MD) 1:1, pigeon pea + finger millet (LD) 1:1 and pigeon pea + finger millet (SD) 1:2 row ratio in intercropping system, respectively but significantly superior to rest of the systems (sole and intercropping) mainly owing to higher production and lower cost of cultivation in these systems. This is in conformity with the result of Ramamoorthy *et al.,* 2004. However, minimum net return and benefit: cost ratio were obtained with pigeon pea and finger millet in 1: 4 row ratio irrespective of duration of finger millet cultivars.

Energetics under different systems

Energy input

In sole cropping system maximum energy input (5218 MJ ha^{-1}) was recorded under finger millet (LD) sole in comparison to finger millet (MD) sole and finger millet (SD) sole ((Table 3). However, minimum energy input (3855 MJ ha^{-1}) was recorded under sole pigeon pea. In intercropping system, maximum energy input (5992 MJ ha^{-1}) was recorded with pigeon pea +finger millet (LD) 1:4 row ratio perhaps due to higher energy input through human and animal labour, seed, fertilizer and chemicals energy. In general, the energy consumption was substantially lower in sole cropping than in intercropping, though the lowest energy consumed when either legumes grown under sole cropping. These results are in agreement with the observations of Pathi and Panigrahi (2006).

Table.1 Yield attributes of pigeon pea and finger millet as influenced by treatments (pooled data of 2 years)

Treatments	Pigeon pea			Finger millet				
	Pods plant^{-1}	Seeds pod^{-1}	100 seed (g)	Effective tillers m^{-1} row	Length (cm) ear^{-1}	Fingers ear^{-1}	Seeds ear^{-1}	1000 seeds wt. (g)
Pigeon pea(PP) sole	129.99	3.37	8.09	-	-	-	-	-
Finger millet (FM,LD) sole	-	-	-	27.90	7.67	6.74	1865	3.23
Finger millet (FM,MD) sole	-	-	-	27.44	7.04	6.40	1835	3.13
Finger millet (FM,SD) sole	-	-	-	27.77	6.24	6.99	1756	3.11
PP +FM (LD) 1:1	63.51	3.18	7.90	26.91	6.98	6.60	1769	3.24
PP +FM (LD) 1:2	57.95	3.08	7.75	26.54	6.94	6.31	1661	3.15
PP +FM (LD) 1:3	47.48	2.93	7.67	24.25	7.18	6.26	1555	3.14
PP +FM (LD) 1:4	37.16	2.89	7.55	23.79	7.30	6.03	1435	3.08
PP+FM (MD) 1:1	76.13	3.21	7.91	25.55	7.12	6.59	1818	3.34
PP+FM (MD) 1:2	63.29	3.05	7.81	24.64	7.49	6.52	1710	3.23
PP+FM (MD) 1:3	55.54	2.98	7.76	22.25	7.54	6.34	1623	3.27
PP+FM (MD) 1:4	43.33	2.95	7.61	21.19	7.55	6.01	1498	3.09
PP +FM (SD) 1:1	82.51	3.25	7.93	25.49	6.90	7.39	1789	3.21
PP +FM (SD) 1:2	69.34	3.13	7.83	24.78	7.04	7.32	1681	3.22
PP+FM (SD) 1:3	58.14	3.05	7.74	23.42	7.46	6.82	1588	3.14
PP +FM (SD) 1:4	45.76	2.95	7.64	21.85	7.83	6.54	1470	3.04
SEm+	3.01	0.17	0.17	1.15	0.32	0.00	84.01	0.30
CD (P=0.05)	8.83	NS	NS	3.34	NS	NS	244.62	NS

LD – Long duration, MD – Medium duration, SD – Short duration, PP: Pigeon pea, FM: Finger millet

Table.2 Pigeon pea grain, stalk/straw yield, pigeon pea equivalent yield and economics as influenced by treatments (Pooled mean of 2 years)

Treatments	Grain yield (q/ ha)		Stalk/Straw yield(qha^{-1})		PEY(q/ha)	Cost of cultivation (Rs/ ha)	Net returns (Rs/ ha)	B:C ratio
	Pigeon pea	Finger millet	Pigeon pea	Finger millet				
Pigeon pea(PP) sole	10.90	-	27.38	-	10.90	5827	11891	2.05
Finger millet (FM,LD) sole	-	25.99	-	66.05	8.67	58805	10495	1.82
Finger millet (FM,MD) sole	-	23.65	-	55.35	7.89	5613	8979	1.61
Finger millet (FM,SD) sole	-	20.95	-	52.20	6.99	5544	7540	1.37
PP +FM (LD) 1:1	7.15	17.10	19.02	20.08	12.85	6884	14345	2.09
PP +FM (LD) 1:2	6.02	18.98	16.10	27.72	12.34	7090	13610	1.93
PP +FM (LD) 1:3	3.50	22.67	10.04	45.08	11.06	7297	12041	1.66
PP +FM (LD) 1:4	2.45	23.32	7.44	51.05	10.23	7439	10821	1.47
PP+FM (MD) 1:1	7.60	15.95	19.72	24.14	12.92	6572	14995	2.29
PP+FM (MD) 1:2	5.83	18.32	15.83	28.10	11.93	6779	13314	1.97
PP+FM (MD) 1:3	3.75	19.63	10.50	40.85	10.29	6985	11019	1.58
PP+FM (MD) 1:4	2.65	20.20	7.71	46.06	9.39	7228	9535	1.33
PP +FM (SD) 1:1	8.30	14.48	20.38	18.33	13.13	6532	15090	2.31
PP +FM (SD) 1:2	6.95	16.15	18.24	27.07	12.34	6742	14023	2.09
PP+FM (SD) 1:3	4.60	17.68	12.21	39.76	10.50	6843	11492	1.69
PP +FM (SD) 1:4	3.25	18.25	8.86	47.10	9.33	7054	9743.5	1.39
SEm ±	0.28	1.04	0.67	1.86	0.40	-	434.39	0.13
CD (P= 0.05)	0.83	3.03	1.97	5.41	1.15	-	1260.68	0.36

Table.3 Energy input &output, gross energy output, energy use efficiency and specific energy, as influenced by treatments (Pooled mean of 2 years)

Systems	Energy input ($MJha^{-1}$)	Gross energy output ($MJha^{-1}$)		Net energy output ($MJha^{-1}$)		Energy use efficiency		Specific energy (MJq-1)
		Grain	Biomass	Grain	Biomass	Grain	Biomass	
Pigeon pea(PP) sole	3855	16023	65298	12168	61443	4.16	16.94	354.18
Finger millet (FM,LD) sole	5218	38212	120775	32994	115557	7.33	23.15	603.11
Finger millet (FM,MD) sole	5185	34765	103953	29580	98768	6.71	20.05	661.68
Finger millet (FM,SD) sole	5175	30061	95311	24900	90136	5.81	18.42	761.08
PP+FM(LD)1:1	5577	35647	94977	30071	89401	6.39	17.04	434.06
PP+FM (LD) 1:2	5618	36735	100359	31117	94741	6.49	17.86	455.34
PP +FM (LD) 1:3	5975	38462	112878	32488	106904	6.44	19.97	540.49
PP +FM (LD) 1:4	5992	37882	120087	31890	114095	6.37	21.15	586.02
PP+FM (MD) 1:1	5528	34618	100290	29091	94762	6.27	18.15	428.07
PP+FM (MD) 1:2	5580	35493	99104	29913	93524	6.37	17.76	467.94
PP+FM (MD) 1:3	5599	34361	104324	28763	98726	6.14	18.63	544.12
PP+FM (MD) 1:4	5623	33589	105042	27967	99420	5.96	18.68	599.47
PP +FM (SD) 1:1	5488	33479	93061	27992	87573	6.10	16.96	418.28
PP +FM (SD) 1:2	5555	33957	100538	28402	95072	6.12	18.12	450.64
PP+FM (SD) 1:3	5588	32744	104422	27156	98834	5.87	18.69	533.14
PP +FM (SD) 1:4	5612	31605	106419	25993	100807	5.65	18.93	601.81
SEm ±	-	-	-	1905.9	7166.3	0.34	0.84	20.90
CD (P=0.05)	-	-	-	5531	20798	0.99	2.44	60.67

LD-Long duration; MD- Medium duration; SD- Short duration

It was interesting to note that the energy input increasing with increasing row ratio of finger millet under pigeon pea + finger millet intercropping system. Higher value of energy input was obtained under pigeon pea + finger millet intercropping with long duration cultivars of finger millet in comparison to medium and short duration cultivars.

Net energy output

Grain

The output energy, however is dependent on yield of component crops. In sole cropping system higher net energy output (32994 MJ ha^{-1}) of grain was obtained with finger millet (LD) sole which was at par with finger millet (MD) sole (29580 MJ ha^{-1}) but significantly superior to finger millet (SD) sole. In intercropping system, pigeon pea + finger millet (LD) 1:3 row ratio recorded maximum net energy output (32488 MJ ha^{-1}) which was at par with all the intercropping system except pigeon pea + finger millet (SD) 1:4 (25993 MJ ha^{-1}).

Biomass

Finger millet (LD) sole recorded maximum net energy output (115557 MJ ha^{-1}) of biomass which was at par with finger millet (MD) sole (98768 MJ ha^{-1}) and significantly superior to finger millet (SD) sole and sole pigeon pea. Minimum net energy output (61443 MJ ha^{-1}) was recorded with pigeon pea sole. In intercropping system, pigeon pea + finger millet (LD) 1:4 row ratio recorded maximum net energy output (114095 MJ ha^{-1}) of biomass which was at par with all the intercropping system except pigeon pea + finger millet (LD) 1:1 (89401 MJ ha^{-1}) and pigeon pea + finger millet (SD)1:1 (87573 MJ ha^{-1}) row ratio. When row ratio of finger millet increased net energy output of grain and biomass increased and maximum net energy output of biomass was recorded with long duration cultivar of finger millet under pigeon pea + finger millet in 1:4 row ratio in intercropping system.

Energy use efficiency and specific energy as influenced by system

Grain

Maximum energy use efficiency (7.33) was obtained with finger millet (LD) sole which was decreased as duration of finger millet decreased. Minimum energy use efficiency (4.16) was recorded with pigeon pea sole. In intercropping system, pigeon pea + finger millet (LD) 1:2 recorded maximum energy use efficiency (6.49) which was statistically alike to all the intercropping treatment combinations. It is interesting to note that energy use efficiency was higher with long duration finger millet (cereal) cultivars in sole as well as intercropping treatment which was decreased with medium and short duration finger millet, respectively. The lowest energy use efficiency was found with sole pigeon pea (legume).

Biomass

Combined analysis of pooled mean revealed that maximum energy use efficiency (23.15) of biomass was obtained with finger millet (LD) sole which was decreased as duration of finger millet decreased. Minimum energy use efficiency (16.94) of biomass was recorded with sole pigeon pea (legume). In intercropping system, pigeon pea + finger millet (LD) 1:4 row ratio recorded maximum energy use efficiency (21.15) which was on par with pigeon pea + finger millet (LD) 1:3 (19.97) and pigeon pea + finger millet (SD) 1:4 (18.93) and significantly superior to rest of the treatment combinations. It is also clear from the data that as the row ratio of finger millet increased energy use efficiency of biomass increased under pigeon pea + finger millet intercropping system.

Specific energy

Results obtained from mean value of both the years of experimentation indicated that minimum specific energy (354.18 MJ q^{-1}) was recorded with sole pigeon pea which was significantly lower to sole finger millet (long,

medium and short duration) as well as intercropping system. In intercropping system, minimum specific energy (418.28 MJ q^{-1}) was recorded with pigeon pea + finger millet (SD) 1:1 which was on a par with pigeon pea + finger millet (MD) 1:1 (428.07 MJ q^{-1}), pigeon pea + finger millet (LD) 1:1 (434.06 MJ q^{-1}), pigeon pea + finger millet (SD) 1:2 (450.64 MJ q^{-1}), pigeon pea + finger millet (LD) 1:2 (455.34 MJ q^{-1}) and pigeon pea + finger millet (MD) 1:2 (467.94 MJ q^{-1}) and significantly superior than rest of the intercropping systems.

It is clear from the results that the minimum specific energy is required by legumes (pigeon pea) and higher by cereals (finger millet). In intercropping systems, specific energy is lower at 1:1 row ratio which was maximum at 1:4 row ratio (higher plant density of finger millet) under pigeon pea + finger millet intercropping system. Higher value of specific energy was found as the number of rows (plant density) of finger millet increases in intercropping system.

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