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Effect of Crop Diversification on Growth and Yield of Pearlmillet (*Pennisetum glaucum* L.) under Custard Apple (*Annona squamosa* L.) Based Rainfed Agri-Horti System

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A field experiment was conducted during the kharif season of 2016 to study the "Effect of crop diversification on growth and yield of pearlmillet (*Pennisetum glaucum* L.) under custard apple (*Annona squamosa* L.) based rainfed agri-horti system.". The highest panicle length. (28.41cm), panicle girth (10.19cm), N. grain/panicle (1767.67) and test weight (15.47g) of pearlmillet and pod length (7.08cm), number of pod/plant (27.06) in pearlmillet + greengram 1:1 and number of grain/pod (33.88), in pearlmillet + sesame 1:2 test weight (285.33g) pearlmillet + groundnut 1:1of sole and intercrop were recorded under different treatment (1:1) and (1:2) in intercropping row ratio. Whereas grain yield (1190.00 kg/ha), straw yield (4209.33 kg/ha), harvest index % (25.55%) and mean pearlmillet grain equivalent yield (4766.49 kg/ha) of pearlmillet and grain yield (775.11 kg/ha), straw yield (1555kg/ha), harvest index % (30.34) sole groundnut treatment of sole or intercrop were highest under pearlmillet sole and other sole treatment as compared to intercropping row ratio.

Keywords: Intercropping, Pearlmillet, greengram, growth, yield, Custard apple and Row Ratios.

Inspite of very substantial gains in agriculture production over the past few decades, the task of meeting the food grains, feed, fodder and fuel needs of increasing human and livestock population remains a formidable challenge before scientific community. In the present situation, increasing agricultural production through extensive agriculture has limited scope due to limited availability of cultivable area. An area of 143.8 million ha out of 329 million of geographical area is at present under cultivation and further expansion of cultivable area is extremely difficult. Under these circumstances, to meet the requirement of food grains for ever increasing population, the only option open is through time and space utilization in agriculture (Sankaran and Rangaswamy, 1990). Rainfed horticulture along with arable crops/fodders is ideal for controlling land degradation. In rainfed areas, the competition between trees and crops for water is a major problem. In agri-horti system, short duration arable crops raised in the interspaces of fruit trees provide seasonal revenue. Intercropping has been recognized as a potentially beneficial system of crop production and evidences indicate that intercropping can provide substantial yield advantage compared with pure cropping (willey, 1979).

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Crop diversification is one of the major components of diversification in agriculture. Crop diversification may be adopted as a strategy for profit maximization through reaping the gains of complementary and supplementary relationships or in equating substitution and price ratios for competitive products. It also acts as a powerful tool in minimization of risk in farming. These considerations make a strong case for farm/crop diversification in India (Chand and chauhan,2002). **a**bnormal occurrence of monsoon is one of the important factors for crop production under rain fed conditions. The principle rainy season crops, grown as sole crop at times are found to be rather risky due to delayed monsoon accompanied with prolonged intermittent dry spells. A strategy for stabilizing production of dry-land crops through commonly recognized practice of intercropping of compatible crops is considered viable to overcome the situation. The system aimed at increasing productivity per unit area and it guarantee insurance against total crop failure, particularly aberrant weather conditions. Patil and Patil (1989) reported beneficial effects of intercropping principal rainy season legumes with pearl millet and gives additional yield also. Therefore, an experiment pearl millet based on intercropping of pulses.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* season of the year 2016 at Research Farm, Rajiv Gandhi South Campus Barkachha Mirzapur (U.P.), Institute of Agriculture Sciences Banaras Hindu University, Varanasi-221005. The soil of the experimental field was sandy loam in texture with low drainage i.e. acidic in nature. It was moderately fertile, being low in organic carbon (0.29%), available nitrogen (202.36 kg/ha), available phosphorus (19.55 kg/ha) and available potassium (235.75 kg/ha). The experiment was laid out in Randomized Block Design with three replications under agri–horti system (fruit based agro forestry system) *viz*., custard apple based Agri-horti system. Treatments were replicated three times. The experiment consisted of 16 treatments *viz.,* T_1: Pearlmillet (Sole); T_2: Greengram(Sole); T_3:Clusterbean(sole) ; T_4:Soybean (sole); T_5: Sesame (sole); T_6: Groundnut (sole); T_7: Pearlmillet + Greengram (1:1); T_8: Pearlmillet + Clusterbean (1:1); T_9: Pearlmillet + Soybean(1:1) ; T_{10}: Pearlmillet + Sesame (1:1) ;$T_{11:}$ Pearlmillet + Groundnut (1:1); $T_{12:}$ Pearlmillet + Greengram (1:2);$T_{13:}$ Pearlmillet + Clusterbean (1:2) ; $T_{14:}$ Pearlmillet + Soybean (1:2) ; $T_{15:}$ Pearlmillet +Sesame (1:2) ;T_{16} Pearlmillet + Groundnut. The seeds were sown with help of kudal directly in rows. The experiment was carried out with nine years old custard apple trees planted at 5 x 5 m spacing. Gross plot size was 3.0 m × 2.0 m. The seed of crops were sown @ 5 kg/ha for pearlmillet, 20 kg ha-1 for greengram , 5 kg/ha for sesame, 20 kg/ha for clusterbean, 65 kg/ha for soyabean, and 100 kg/ha for groundnut lines spaced as per treatments in sole cropping. In intercropping treatments row to row distance maintained was 30 and 10 cm and sowing was done by "furrow" method by kudal . The crops were sown on 12 Aug 2010 with the onset of monsoon rains using 'ICMV-155' pearlmillet , 'HUM-16'greengram, "Muskan (guar)" cluster bean, "AHILYA-4" variety soybean, sesame "shekhar" variety and variety "GJG-9" groundnut. The recommended fertilizer does for 80 kg N/ha nitrogen was applied through urea and DAP, 40 kg P2O5/ha phosphorus through DAP and 40 kg K2O/ha. Potassium through MOP prior to sowing was applied only in pure crops. In intercropping combinations seed rate and fertilizers were adjusted according to the number of row arrangement. The other agronomic practices were followed as per recommendation.

Experimental design, data collection and analysis

Regarding agronomic characters, five competitive plants were randomly selected from each plot and observations were recorded for growth attributes, yield attributes and yield The data were analyzed as per standard statistical procedure (RBD) suggested by Gomez and Gomez (1984).

Pearlmillet equivalent yield

Seed yield of Cluster bean was calculated in terms of Pearlmillet for all intercropping treatments. On the basis of their market price and then analyzed statistically as equivalent grain yield of Pearlmillet treatment using the following formula:

Pearlmillet grain yield of equivalent yield = Yield of intercrop × price of intercrop +PGY(kg. ha^{1})/ Price of pearlmillet (Rs.kg^{-1})

Land equivalent ratio

It denotes the relative land area under sole crop required to produce the same yield as obtained under a mixed or an intercropping system at the same management level. It is calculated as sum total of the ratios of yield of each component crop in an intercropping system to its corresponding yield when grown as a sole crop thus:

LER = Y ab+ Y ba/Y aa + Y bb

Where,

Y ab = is the yield of crop 'a' in association with crop 'b'

Y ba = is the yield of crop 'b' in association with crop 'a'

Y aa = is the pure stand yield of crop 'a'

Y bb = is the pure stand yield of crop 'b'

Experimental result and analysis

The results obtained from the present study have been discussed in detail under following heads:

Growth attributes

Plant height of pearlmillet at maturity was statistically equal, but found higher in sole pearlmillet as compared to pearlmillet with intercrops (Table 1.) which might be attributed to higher cell elongation due to auxin accumulation in plants (Malik and Srivastava, 1982) and (Choudhary, 2009) moreover, light availability was comparatively lesser due to higher plant densities under sole crop. In sole cropping of pearlmillet, plant height increased due to competition for sunlight among the plants. The shorter plants of pearlmillet were found when intercropped at 1:1 and 1:2 row ratios with Pearlmillet + Greengram. This was due to interspecies and cooperative interaction of intercrops with pearlmillet for non renewable resources like water, nutrients and light. These results corroborated with the finding of Baldevram *et al*. (2014).

The effect of different treatments on number of effective tillers, number of leaves and dry matter accumulation per plant had significant and higher number was observed in millet + Greengram (1:1) followed by Sole Pearlmillet, Pearlmillet + Greengram (1:2) row ratio and (1:2), and minimum in Pearlmillet + Sesame (1:2) (Table 1.). This was might be due to development of better complementary relationship and non-renewable resources like water, nutrients and incoming sunlight. These results are also conformity with those reported by Rathore and Gautam (2003) and Choudhary (2009) who observed that significantly higher number of effective tillers per plant was obtained under pearlmillet crop sown with greengram.

All the intercrops noticed higher plant height as compared to their sole cropping which attributed to shedding effect of taller plants of pearlmillet on pulses and competition for sun light resulted into elongation of their main stem (Table 1). These results were in agreement with finding of Kulkarni and Sojitra (1986) and Choudhary (2009) who observed that tall growing cereals had a shedding effect on the greengram and groundnut crop canopy and increased height .

The differences in number of branches per plant were reduced in both the row ratios of intercropping systems as compared to their sole cropping which perhaps due to the fact that competition offered by pearlmillet for natural resources, resulted in poor development of intercrops and also due to less space available for horizontal spread of plants and intraspecific competition for incoming sun radiation (Table 1). These results are in conformity with findings of Parmar (1989) and Choudhary (2009) who observed that intercropping of pearlmillet reduce the number of branches per plant of clusterbean and soybean.

Yield attributes

Length and girth of pearlmillet ear head and 1000- grain weight showed lack of significant effect regarding the effects of different treatments. Higher values of length and girth of pearlmillet ear head as well as 1000-grain weight were registered when, Pearlmillet + Greengram each at 1:1 row ratio and Sole pearlmillet (Table 2). This might be due to development of better complementary effect of pulses on pearlmillet and nonrenewable resources like water, nutrients, space and incoming Solar radiation. Rathore and Gautam (2004) who observed that intercropping of pearlmillet with cowpea and greengram gave higher 1000-grain weight.

Significantly higher grain yield per

Table 1. Effect crop diversification on final plant height, number of total tillers/ branches per plant, effective tillers of pearlmillet and sole or intercropping

Treatment	Final plant height (cm)		Final Number of total tillers and branches per plant		Final Numbers of leaves" trifoliate leaves per plant		Final Dry matter accumulation (g)	
	Pearlmillet	Sole or intercrops	Pearlmillet	Sole or intercrops	Pearlmillet	Sole or intercrops	Pearlmillet	Sole or intercrops
T_1 : Pearlmillet (Sole)	242.26	_	2.49	_	12.23	_	65.99	_
T_2 : Greengram (Sole)	_	38.40	_	8.70	_	5.88	_	40.10
T_3 : Clusterbean(sole)	_	43.11	_	6.37	_	4.65	_	26.54
T_4 : Soybean (sole)	_	43.60	_	6.24	_	5.09	_	24.22
T_5 : Sesame (sole)	_	130.41	_	11.47	_	46.00	_	46.02
T_6 : Groundnut (sole)	_	36.25	_	10.74	_	22.09	_	35.52
T_7 : Pearlmillet +Greengram (1:1)	245.98	38.21	2.74	7.42	12.42	5.32	91.33	38.56
T_8 : Pearlmillet +Clusterbean (1:1)	241.10	41.62	2.37	6.90	11.68	4.85	89.07	26.54
T_9 : Pearlmillet + Soybean(1:1)	239.40	44.20	2.28	6.41	11.29	4.97	89.05	25.47
T_{10} : Pearlmillet + Sesame (1:1)	225.45	134.90	1.74	11.66	11.03	46.37	67.78	48.60
T_{11} : Pearlmillet + Groundnut (1:1)	235.78	36.87	2.28	11.32	11.24	21.38	82.48	35.49
T_{12} : Pearlmillet +Greengram (1:2)	243.92	38.40	2.66	7.50	12.26	5.28	89.09	39.12
T_{13} : Pearlmillet + clusterbean (1:2)	235.76	42.87	2.31	6.54	11.51	4.97	73.45	26.56
T_{14} : Pearlmillet + soybean (1:2)	241.67	42.57	2.13	6.27	11.25	4.89	68.93	25.71
T_{15} : Pearlmillet +sesame (1:2)	226.66	129.17	1.78	11.44	11.15	44.24	68.63	49.74
T_{16} : Pearlmillet + Groundnut (1:2)	229.00	36.27	2.44	11.01	11.27	21.38	81.07	36.78
S E m±	0.44	0.19	0.05	0.09	0.13	0.16	0.25	0.07
CD	1.30	0.56	0.14	0.25	0.39	0.47	0.75	0.20

Table 2. Effect of crop diversification on yield attributes of pearlmillet and sole or intercrop.

Treatment	Pearlmillet				Sole or intercrops			
	Panicle length	Panicle girth	N .grain / panicle	Test weight (g)	Number of pod/plant	Pod length (cm)	Number of grains per pod	Test weight (g)
T_1 : Pearlmillet (Sole)	25.1	9.37	1676.83	14.24	_	_	_	_
T_2 : Greengram (Sole)	_	_	_	_	25.57	6.50	9.43	47.82
T_3 : Clusterbean(sole)	_	_	_	_	18.14	6.40	13.07	34.33
T_4 : Soybean (sole)	_	_	_	_	12.26	3.93	3.00	65.67
T_5 : Sesame (sole)	_	_	_	_	16.07	3.43	30.41	3.23
T_6 : Groundnut (sole)	_	_	_	_	23.03	4.47	4.00	281.67
T_7 : Pearlmillet +Greengram (1:1)	28.41	10.11	1767.67	15.47	27.06	7.08	11.03	49.03
T_8 : Pearlmillet +Clusterbean (1:1)	23.97	8.56	1647.33	13.62	17.94	6.57	14.36	35.50
T_9 : Pearlmillet + Soybean(1:1)	22.73	8.30	1425.33	11.79	13.97	3.30	2.70	65.81
T_{10} : Pearlmillet + Sesame (1:1)	18.16	7.68	1126.33	11.14	18.10	2.77	32.24	2.94
T_{11} : Pearlmillet + Groundnut (1:1)	22.42	8.10	1560.00	14.07	23.18	4.17	2.60	285.33
T_{12} : Pearlmillet +Greengram (1:2)	26.45	10.19	1745.67	14.71	26.37	7.33	13.33	47.61
T_{13} : Pearlmillet + clusterbean (1:2)	24.51	8.56	1642.33	13.41	18.46	6.30	11.67	34.82
T_{14} : Pearlmillet + soybean (1:2)	23.57	8.56	1506.00	13.06	14.35	3.72	4.06	69.31
T_{15} : Pearlmillet +sesame (1:2)	18.91	7.74	1176.67	11.92	18.05	3.27	33.88	2.95
T_{16} : Pearlmillet + Groundnut (1:2)	23.21	8.66	1537.67	14.01	22.67	4.27	4.16	283.33
S E m±	0.08	0.06	2.77	0.08	0.19	0.04	0.05	0.05
CD	0.24	0.17	8.16	0.23	0.54	0.12	0.16	0.13

Table 3. Effect of sole crop and intercropping treatments on test weight, grain yield per ear head, seed yield, straw yield and harvest index of pearlmillet and intercrops

Treatment	Grain/seed yield (kg ha-1)		Straw/Stover yield (kg ha-1)		Harvest index %			
	Pearlmillet	Sole or	Pearlmillet intercrops	Sole or	Pearlmillet intercrops	Sole or	PGER intercrops	LER
T_1: Pearlmillet (sole)	1190.00	_	4209.33	_	25.55	_	4766.49	1.0
T_2: Greengram (sole)	_	775.11	_	1396.11	_	24.66	_	1.0
T_3: Clusterbean(sole)	_	714.96	_	1438.67	_	26.78	_	1.0
T_4: Soybean (sole)	_	689.97	_	1279.33	_	23.15	_	1.0
T_5: Sesame (sole)	_	470.19	_	1106.33	_	21.56	_	1.0
T_6: Groundnut (sole)	_	577.62	_	1555.00		30.34	_	1.0
T_7: Pearlmillet +Greengram (1:1)	805.00	702.40	3343.33	1209.00	24.48	23.73	4385.46	2.03
T_8: Pearlmillet + Clusterbean(1:1)	771.30	667.77	3185.67	1302.67	22.44	25.77	4358.13	1.18
T_9: Pearlmillet + Soybean(1:1)	568.67	620.33	2809.00	968.67	19.09	23.09	4291.00	1
T_{10}: Pearlmillet + Sesame (1:1)	521.77	430.33	2640.67	1037.33	17.87	21.04	4255.79	1.7
T_{11}: Pearlmillet + Groundnut (1:1)	578.02	524.26	2959.00	1478.00	20.78	28.99	4255.81	1.3
T_{12}: Pearlmillet +Greengram (1:2)	781.17	720.00	3270.33	1279.33	23.91	24.14	4380.22	2.01
T_{13}: Pearlmillet + Clusterbean (1:2)	665.67	676.00	3070.97	1241.67	22.33	26.01	4354.00	1
T_{14}: Pearlmillet + soybean (1:2)	552.33	644.33	2777.67	1067.00	20.09	24.02	4254.50	1
T_{15}: Pearlmillet +sesame (1:2)	522.33	435.33	2593.33	1155.33	17.06	20.45	4259.33	1.18
T_{16}: Pearlmillet + Groundnut (1:2)	525.00	586.48	2811.63	1503.67	20.45	29.51	4321.13	1.33
S E m±	0.57	0.11	8.62	0.23	0.08	0.02	5.32	0.014
CD	1.68	0.32	25.43	0.67	0.24	0.06	15.69	0.048

Table 4. Relative economics

Treatment	Economics			
	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (R s . / h a)	B:C Ratio
T_1: Pearlmillet (Sole)	17714	47248	29534	1.66
T_2: Greengram (Sole)	16819	56248	39429	2.34
T_3: Clusterbean(sole)	14985	44658	29673	1.98
T_4: Soybean (sole)	15001	51154	36153	2.41
T_5: Sesame (sole)	13928	53430	39502	2.83
T_6: Groundnut (sole)	39593	83840	44247	1.11
T_7: Pearlmillet +Greengram (1:1)	11416	34219	22803	1.99
T_8: Pearlmillet +Clusterbean (1:1)	16011	34916	18905	1.18
T_9: Pearlmillet + Soybean(1:1)	14618	31759	17141	1.17
T_{10}: Pearlmillet + Sesame (1:1)	13928	37546	23618	1.69
T_{11}: Pearlmillet + Groundnut (1:1)	30268	84307	54039	1.78
T_{12}: Pearlmillet +Greengram (1:2)	12109	39860	27751	2.29
T_{13}: Pearlmillet + clusterbean (1:2)	17015	35650	18635	1.09
T_{14}: Pearlmillet + soybean (1:2)	14890	32233	17343	1.16
T_{15}: Pearlmillet +sesame (1:2)	14208	39660	25452	1.79
T_{16}: Pearlmillet + Groundnut (1:2)	32375	69546	37171	1.14

plant was recorded at intercrop 1:1 and 1:2 as compared to Sole Pearlmillet system which could be attributed to higher and optimum plant densities in sole cropping system.

Significantly the highest grain and straw yields were recorded by sole pearlmillet than rest of the intercropping treatments, which could be attributed to higher and optimum plant densities in sole cropping system. Lower significant grain and straw yields were noticed under pearlmillet + Sesame 1:1 and 1:2, row ratio intercropping system (Table 2).

Length of the pod and 1000-seed weight of all intercrops was reduced in both the row ratios of intercropping system than their sole cropping (Table 2). This might due to fact that intra-specific competition for space, soil moisture, plant nutrients and sunlight. These results are in agreement with finding of Gadhia (1991) and Choudhary (2012). Number of pods per plant, seeds per pod and seed yield per plant of intercrops were reduced in intercropping systems as compared to their sole cropping (Table 2) which might be due to the fact that competition offered by pearlmillet for natural resources, resulted in poor development of intercrops and also due to less space available for horizontal spread of plants and intra-specific competition for solar radiation. The results are corroborate with the findings of Patel and Parmar (2013) and Choudhary (2012), who observed that intercropping of pearlmillet reduce the pods per plant of Soybean and Sesame.

Significantly higher grain yield per plant was recorded at intercrop 1:1 and 1:2 as compared to Sole Pearlmillet system which could be attributed to higher and optimum plant densities in sole cropping system.

Significantly the highest grain and straw yields were recorded by sole pearlmillet than rest of the intercropping treatments, which could be attributed to higher and optimum plant densities in sole cropping system. Lower significant grain and straw yields were noticed under pearlmillet + Sesame 1:1 and 1:2, row ratio intercropping system (Table 3).

A critical analysis of data clearly indicates that there was significant variation in harvest index due to different treatments. The data revealed that the maximum harvest index (HI) was recorded in Sole Pearlmillet (T1) which was at par with Pearlmillet + Greengram (1:1) (T7) and Pearlmillet + Greengram (1:2*)* (T12). Minimum harvest index

was recorded under Pearlmillet + Sesame (1:2) (T15) treatment.

A critical analysis of data clearly indicates that there was significant variation in harvest index due to different treatments. However, the maximum harvest index (HI) was recorded under Sole Groundnut (T6) treatment followed by Pearlmillet + Groundnut (1:1) (T11), Pearlmillet + Groundnut (1:2) (T16) and Sole Clusterbean (T3) respectively. The minimum harvest index was recorded under Pearlmillet + Sesame (1:2) (T15) treatment.

PGER and LER

Data presented in Table 3. indicated that intercropping treatments significantly influenced the pearlmillet grain equivalent yield. The maximum mean pearlmillet grain equivalent yield (4766.49 kg ha-1) was obtained under pearmillet sole significantly higher than all other treatments. Land equivalent ratio (LER) implies the relative land area under sole crops that is required to produce the yields achieved in intercropping under same level of management. (Dan singh *et al.*2011)

The land equivalent ratio treatments were significantly higher than sole pearlmillet. Among the intercropping treatments, row ratio have pearlmillet + greengram (1:1) maximum LER 2.03 followed by 2.01 under row ratio pearlmillet +greengram (1:2). Ghilotia *et al.* (2014) also reported that land equivalent ratio (1.04) was observed in pearlmillet + mungbean (2:2) intercropping.

Relative economics

The data on relative economics of various treatments revealed that the maximum net return Pearlmillet + Groundnut (1:1) (Rs. 54039/ha) and B:C ratio (2.83) were recorded in Sole Sesame This may be due to the fact that Sole greengram treatment increased the grain and straw yield (Table.4). Hooda *et al*. (2004), Kuri *et al*. (2012) also reported that Pearlmillet + Groundnut (1:1) intercropping of recorded highest net return and B : C ratio over sole and inter crop.

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