Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(2): 1671-1675
Received: 01-01-2018
Accepted: 02-02-2018

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Performance of advance pearl millet hybrids and mungbean under sole cropping and intercropping systems under semi arid environment

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Abstract
A field experiment was conducted during *Kharif* 2015 at Research Farm of the Department of Genetics and Plant Breeding, CCS Haryana Agricultural University; Hisar to study the performance of newly released hybrids of pearl millet intercropped with green gram. The experiment was laid out in Randomized Block Design (RBD) with three replication and nine treatments comprising of five sole treatments having four pearl millet hybrids (HHB 67 Improved, HHB 197, HHB 226 and HHB 234) and one variety of green gram (MH 421) and four intercropping treatments (pearl millet hybrids + green gram). The results revealed that growth parameters per plant and yield contributing traits among pearl millet hybrids were decreased by the intercropping of green gram. Among all the sole and intercropping treatments, the pearl millet hybrid HHB 197 intercropping with green gram variety MH 421 exhibited its superiority in respect of pearl millet equivalent yield, gross returns, net returns and benefit-cost ratio. The intercropping of this hybrid with green gram was also found most compatible as indicated by the higher values of the biological parameters *viz.*, land equivalent ratio, area time equivalent ratio), total crowding coefficient, aggressively, competition ratio, monetary advantage index and income equivalent ratio as compared to all other pearl millet hybrid based intercropping systems.

Keywords: pearl millet, green gram, intercropping, biological parameters, gross & net returns (Rs/ha)

Introduction
Pearl millet [*Pennisetum glaucum* (L.) R.Br.] is the third most important food grain crop in India. India is the largest producer of pearl millet in the world occupying an area of 7.1 million hectare, production of 9.1 million tonne per year with average productivity of 12.72 q/ha (Anonymous, 2015) [1]. Being inherent drought-escaping mechanism and adaption to drier and low fertile conditions, it occupies a prime place in dryland agriculture and contributing significantly to country's food security. Globally as well as locally, limited availability of additional land for crop production and declining soil fertility has raised concerns about the sustainability of agricultural production at current levels. Thus, strategies for increasing and sustaining agricultural productivity will have to focus on using available land and nutrient resources more effectively than in the past. This objective can be achieved by inserting an additional population of a second crop through suitable alteration in normal planting geometry of the main crop, commonly known as intercropping.
Farmers in the arid and semi arid regions practice generally mix/intercrop pearl millet with legumes to increase productivity per unit area or avoid risk of failure of crops as the legume crops, especially mungbean are more stable in grain yields in arid region (Ram and Meena 2014) [14]. Many new hybrids of pearl millet are being released for rainfed situation and they may respond differently with intercrop green gram. Information is scanty regarding comparative performance of these new pearl millet hybrids intercropping with green gram as intercrop. In order to obtain more information with regard to the complementary effect of green gram intercropping on different newly released hybrids of pearl millet under semiarid conditions the present investigation was carried out.

Materials and Methods
The field experiment was conducted at Research Farm of the Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, which is situated at latitude of 29°10' North, longitude of 75°46' East and elevation of 215.2 m above mean sea level in the subtropical climate zone of India. The experiment was laid out in Randomized Block Design (RBD) with nine treatments *viz*, The sole crop of four pearl millet hybrids; T_1= HHB 67 Improved, T_2= HHB 197, T_3= HHB 226, T_4= HHB 234 along with four intercropping systems of these hybrids with green gram variety MH 421 *viz.* T_5=HHB 67

Improved + MH 421 (2:1), T_6=HHB 197 + MH 421 (2:1), T_7=HHB 226 + MH 421 (2:1), T_8= HHB 234 + MH 421 (2:1) and Sole MH 421 of Green gram crop (T_9). The sowing of main as well as intercrop was done manually in flat beds with the help of a hand plough. The sole crop of pearl millet and green gram was sown in rows 45 cm apart, whereas, in intercropping treatments, sowing was done in paired row of 30:60 cm spacing to achieve equal number of rows for main crop both in sole and intercropping stands. One row of green gram was inserted in 60 cm row spaced pearl millet crop. The sowing was done on 3rd July 2015 using seed rate 5 and 25 kg/ha for pearl millet and green gram crops, respectively.

The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH=8.0), low in organic carbon (0.33 %) and available nitrogen (135 kg/ha), medium in available phosphorus (18.0 kg/ha) and potassium (260 kg/ha). A total rainfall of 220.3 mm (July to September) was received during the crop season. The rainfall received was 156.1, 54.8 and 9.4 mm during July, August and September month, respectively. Pre-sowing field preparation was done after the receipt of rainfall on 25th June (55.8 mm) and then 3.5 and 9.7 mm rainfall was received on 27th and 30th June, respectively, which again was utilised for crop sowing. A uniform dose of nitrogen 40 and phosphorus 20 kg/ha was drilled in the field as basal dose through urea and diammonium phosphate. The potash was not applied since the soil of the experimental field was rich in available potassium. The nitrogen and phosphorus @ 20 and 40 kg/ha, respectively were applied to sole green gram as per the recommendation.

Periodical observations on growth parameters of pearl millet were recorded at 20, 40, 60 days after sowing (DAS). The grain, straw and biological yield were recorded for both pearl millet and green gram at harvesting. The economics of various treatments was calculated in ters of gross returns (Rs/ha), net returns (Rs/ha) and B:C ratio. The assessment of yield advantage were calculated as per the following indices;

Land equivalent ratio

Land equivalent ratio of different intercropping system was calculated by the following formula given by Willey (1979) [17]:

$$LER = La + Lb,\ La = Yab/Yaa,\ Lb = Yba/Ybb$$

Where, La and Lb are land equivalent ratio of main and intercrops, respectively. Yaa and Yab are yield of main crop. Ybb and Yba are the yield of intercrop in sole stands and in intercropping, respectively

Area-time equivalent ratio

It takes into account the duration of the crops and permits an evaluation of crops yield per day basis. It is calculated by the following formula of Hiebsch and Mc-Collum (1987):

$$ATER = \frac{La\ X\ Ta + Lb\ x\ Tb}{T}$$

Where, La and Lb are partial LER of component crops A (pearl millet) and B (green gram). Ta and Tb are duration of crops A and B.T is total duration of the intercropping system

Income equivalent ratio

It is just conversion of land equivalent ratio (LER) into economic terms. It is calculated by the following formula:

$$IER = \frac{Ya}{Sa} + \frac{Yb}{Sb}$$

Where, Ya and Yb are value of produce (Rs./ha) of individual crop in intercropping system. Sa and Sb are the values of produce of sole crops

Monetary advantage index

Monetary advantage index (MAI) refers to an index by taking into account the relative money value of produce under intercropping system.

$$MAI = \text{Value of combined yield of intercropping system X } \frac{LER-1}{LER}$$

Where, LER is land equivalent ratio**.**

Aggressivity of main crop: It was proposed by Mc-Gilchrist (1965). Aggressivity gives simple measure of how much the relative yield increase in component .a. is greater than that for component .b. It is usually denoted by A.

$$(Aab) = \{(Yab/Yaa \text{ x } Zab).\ (Yba/Ybb \text{ x } Zba)\}$$

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.

Zab = Sown proportion of component .a. in combination .b.

Zba = Sown proportion of component .b. in combination .a.

Relative crowding coefficient

Relative crowding coefficient was proposed by de-Wit (1960) [3]. Each component has its own coefficient (K), which gives a measure of whether that component has produced more or less yield than expected. It can be calculated by the following formula

$$K = Kab \text{ x } Kba$$

$$K = \frac{Yab\ X\ Zba}{(Yaa-Yab)X\ Zab}\ X\ \frac{Yba\ X\ Zab}{(Ybb-Yba)\ X\ Zba}$$

K = Relative crowding coefficient of the intercropping system

Kab = Relative crowding coefficient of main crop, Kba = Relative crowding coefficient of intercrop

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.

Zab = sown proportion of component .a. in combination .b., Zba= sown proportion of component .b. in combination .a.

Competitive ratio

Competitive ratio is simply the ratio of individual LERs of the two component crops but correcting for the proportion, in which, they were initially sown (Willey and Rao, 1980) [16].

$$CR = CR\ a + CR\ b$$
$$CR\ a = (LER\ a\ /LER\ b)\ x\ (Z\ ba/Z\ ab)$$
$$CRb = (LER\ b/LER\ a)\ x\ (Z\ ab/Z\ ba)$$

Where,

CRa = Competitive ratio for main crop pearl millet,

CRb = Competitive ratio for intercrop green gram
LERa = Partial LER of component .a., LERb = Partial LER of component .b.
Zab = Proportion of intercrop area allocated to main crop
Zba = Proportion of intercrop area allocated to intercrop
The economics of various treatments was calculated in terms of gross returns (Rs/ha), net returns (Rs/ha) and B:C ratio.

Results and Discussion

Growth parameters

Among sole and intercropping treatments, no significant difference was observed in plant height of pearl millet hybrids at initial stage (20 DAS) of crop growth. In general, plant height of pearlmillet sole and intercropping increase with the advancement of crop growth but, the plant height of pearl millet hybrids decreased significantly from 40 DAS until harvest by intercropping of green gram variety MH 421 as compared to their respective sole stands. Intercropped plants may decrease (Lawson *et al.*, 2007) [11], increase (Misra, 1996) [13] or maintain their normal height (Singh and Khan, 2003) [15] depending on the nature of interference of the component crops. The maximum plant height at harvest was recorded in the sole HHB 197 hybrid. Leaf Area Index (LAI) increased considerably at 40 and 60 DAS, and thereafter, these values decreased. The parameters of LAI in pearl millet hybrids were decreased by intercropping of green gram as compared to their sole stands (Fig.1). The trend of dry matter accumulation (DMA) depicted from figure 1 shows pearl millet hybrids DMA/plant decreased significantly with intercropping of green gram as compared to sole pearl millet hybrids. At harvest, maximum dry matter per plant was recorded in HHB 197 hybrid followed by HHB 226, and both the hybrids were found significantly superior to HHB 67 Improved and HHB 234 in sole as well as intercropping treatments. Intercropping has been found to decrease the LAI, growth rate and net assimilation rate due to increased competition for the available resources (Gardiner and Cracker, 1981) [4].

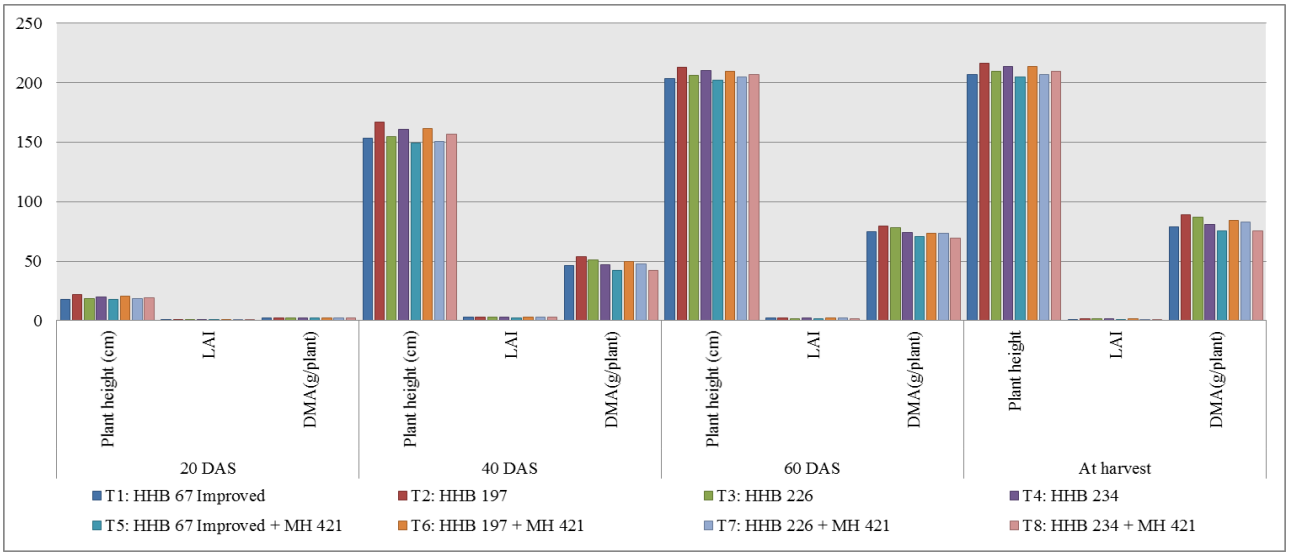

Fig 1: Periodical changes in plant height (cm), Leaf area index (LAI) and dry matter accumulation (DMA) g/plant of pearl millet

Yield attributes and yield

Yield of a crop is the function of interaction between genetic potential of the crop cultivar and the environment. When two or more crops are grown in association, the genetic potential being constant, environment component is modified, *per se* affecting the different components of yield. The sole pearl millet hybrids produced more number of total and effective tillers per plant, ear head length, ear head girth and test weight as compared to their respective intercropping treatments at the time of harvest. The hybrid HHB 197 produced maximum number of effective tillers per plant followed by its intercropping treatment. The same trend of effective tillers was also observed for earhead length, earhead girth and test weight. The pearl millet grain, stover and biological yield were observed maximum in sole pearl millet hybrid HHB 197, which was found comparable to sole HHB 226 and its own intercropping system with green gram but significantly superior to the remaining treatments. Intercropping of green gram with pearl millet hybrids in 2:1 row ratio produced statistically at par grain yield as compared to their respective sole hybrid stands. The harvest index of pearl millet hybrids was not significantly influenced by various treatments (Table1). Similar findings were reported by Baldev *et al.* (2003) [2] and Yadav and Yadav (2001) [18].

Table 1: Effect of different intercropping treatments on yield attributes and yields of pearl millet hybrids

Treatments	Total tillers/ plant at harvest	Effective tillers/plant at harvest	Earhead length (cm)	Earhead girth (cm)	Test weight (g)	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)
T_1: HHB 67 Improved	3.2	2.3	20.7	2.3	8.6	22.22	65.26	87.48	25.4
T_2: HHB 197	3.9	2.8	23.7	2.7	9.0	27.58	74.66	102.24	26.9
T_3: HHB 226	3.5	2.6	21.7	2.6	7.9	25.52	71.99	97.51	26.2
T_4: HHB 234	3.4	2.3	23.3	2.2	7.5	23.54	67.29	90.83	25.9
T_5: HHB 67 Improved + MH 421	3.0	2.1	20.5	2.2	8.4	20.34	60.21	80.54	25.2
T_6: HHB 197 + MH 421	3.6	2.6	23.5	2.6	8.8	26.63	71.42	98.04	27.1
T_7: HHB 226 + MH 421	3.3	2.4	21.4	2.5	7.8	24.10	69.82	93.92	25.7
T_8: HHB 234 + MH 421	3.2	2.3	23.0	2.1	7.3	21.29	61.31	82.60	25.7
CD at 5%	0.4	0.4	2.1	0.4	0.6	3.01	3.82	5.89	NS

Competition indices

The intercropping of HHB 197 and HHB 226 with green gram variety MH 421 exhibited the highest LER value of 1.29, indicating the superiority over HHB 67 Improved and HHB 234 hybrids. Similarly, the maximum ATER was obtained in intercropping of HHB 197 pearl millet hybrid with green gram followed by HHB 67 Improved + green gram and HHB 226 + green gram treatments, respectively. Ghilotia *et al*. (2015) [5] reported that the land equivalent ratio was significantly higher in intercropping than sole treatments. The main crop of pearl millet had positive values of aggressivity and the intercrop green gram had negative values. This indicates that pearl millet was the dominant component in intercropping system, and green gram was the dominated one. The highest value of aggressivity was recorded in HHB197 based intercropping treatment followed by HHB 226 based system. The total crowding coefficient was higher in intercropping systems of HHB 197 (1.8) and HHB 226 (1.4) with green gram indicating yield advantage as these values were more than unity. The highest competitive ratio was observed in pearl millet hybrid HHB 197 + green gram system followed by HHB 226, HHB 67 Improved and HHB 234 based intercropping systems, thereby indicating that all these hybrids had produced more than expected yield in pearl millet and were more competitive too. The highest monetary advantage index (MAI) and income equivalent ratio (IER) were realised in the HHB 197 + green gram intercropping system, which was followed by HHB 226 + green gram, HHB 234 + green gram and HHB 67 Improved + green gram treatments, respectively (Table 2).

Table 2: Effect of different intercropping treatments on various yield indicies in pearl millet-mungbean intercropping system

Treatments	LER	ATER	Aggressivity		Crowding coefficient			Competitive ratio		MAI	IER
			Pearl millet	Green-gram	Pearl millet	Green-gram	Total	Pearl millet	Green-gram	(Rs./ha)	
T_5: HHB 67 Improved + MH 421	1.25	1.24	0.371	-0.371	7.07	0.11	0.8	5.51	0.18	4042	1.25
T_6: HHB 197 + MH 421	1.29	1.25	0.457	-0.457	16.01	0.11	1.8	5.88	0.17	6852	1.29
T_7: HHB 226 + MH 421	1.29	1.24	0.389	-0.389	11.85	0.12	1.4	5.73	0.18	6033	1.29
T_8: HHB 234 + MH 421	1.27	1.21	0.110	-0.110	4.93	0.13	0.6	4.89	0.20	4844	1.28

Pearl millet equivalent yield and Economics

The intercropping of green gram with different pearl millet hybrids gave significantly higher pearl millet equivalent yield than their sole cultivation. Similar results were reported by Kumar *et al.* (2005) [8] and Kumar *et al*. (2006) [9]. However, among all the sole and intercropping treatments, the intercropping of green gram with HHB 197 produced the highest pearl millet equivalent yield of 42.58 q/ha. The intercropping of different pearl millet hybrids with green gram resulted in higher gross and net returns than their respective sole hybrids. The intercropping of green gram in 2:1 row ratio with pearl millet hybrid HHB 197 gave maximum gross and net returns. The benefit-cost ratio was also obtained maximum when pearl millet hybrid HHB 197 (2.3) was intercropped with green gram, followed by its sole treatment with a value of 2.2(Table 3) Hooda *et al*. (2004) [7], Kuri *et al*. (2012) [10] also reported that intercropping of pearlmillet with green gram recorded highest net return and B:C ratio over sole pearlmillet.

Table 3: Effect of different intercropping treatments on pearl millet equivalent yield and economic in pearl millet-mungbean intercropping system

Treatments	PEY (q/ha)	Gross returns (Rs./ha)			Cost of cultivation (Rs./ha)			Net returns (Rs./ha)			B:C
		Pearl millet	Green-gram	Total	Pearl millet	Green-gram	Total	Pearl millet	Green-gram	Total	
T_1: HHB 67 Improved	31.44	40082	-	40082	22553	-	22553	17529	-	17529	1.8
T_2: HHB 197	38.12	48603	-	48603	22553	-	22553	26050	-	26050	2.2
T_3: HHB 226	35.68	45500	-	45500	22553	-	22553	22947	-	22947	2.0
T_4: HHB 234	33.04	42129	-	42129	22553	-	22553	19576	-	19576	1.9
T_5: HHB 67 Improved + MH 421	34.81	36767	7608	44375	22553	1566	24119	14214	6042	20256	1.8
T_6: HHB 197 + MH 421	42.58	46804	7481	54285	22553	1566	24119	24251	5915	30166	2.3
T_7: HHB 226 + MH 421	40.06	43297	7778	51075	22553	1566	24119	20744	6212	26956	2.1
T_8: HHB 234 + MH 421	36.56	38181	8430	46611	22553	1566	24119	15628	6864	22492	1.9
T_9: Sole MH 421	17.90	-	22829	22829	-	20706	20706	-	2123	2123	1.1
CD at 5%	2.92	-	-	-	-	-	-	-	-	-	-

Note: *PEY- Pearl millet equivalent yield*; MSP of pearl millet grain Rs. 1275/q and stover Rs. 180/q; MSP of mung bean grain Rs. 4850/q and stover Rs. 80/q

Conclusion

Based upon one year data of the present investigation, it is concluded that the growth attributes (plant height, LAI, total tillers and dry matter accumulation per plant) and yield contributing traits (effective tillers per plant, earhead length, earhead girth and test weight) among pearl millet hybrids were decreased by the intercropping of green gram. However, all the intercropping treatments in terms of pearl millet equivalent yield (PEY), the gross returns, net returns and benefit-cost ratio exhibited their superiority over their respective sole stands. The economic analysis of sole and intercropping treatments reveals that the intercropping of green gram variety MH 421 with pearl millet hybrid HHB 197 gave maximum pearl millet equivalent yield (42.58 q/ha), gross returns (Rs. 54285/ha), net returns (Rs. 30166/ha) and benefit-cost ratio (2.3).

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