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Evaluation of cotton hybrids for productivity potential, monetary and energy returns under varied agronomic manipulations

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ABSTRACT : A field experiment was conducted during *kharif* 2016 at Punjab Agricultural University, Regional Research Station, Bathinda to evaluate performance of two American cotton hybrids (HHH 494 and CSHH 2012) under three spacing levels (67.5×60 cm, 67.5×75 cm and 67.5×90 cm) and three nitrogen levels (112.5, 150 and 187.5 kg/ha) in split split plot design and replicated thrice. Significantly higher number of bolls/ plant contributed to significantly higher seed cotton yield (SCY) of hybrid CSHH 2012 (2817 kg/ha) in comparison to HHH 494 (2468 kg/ha). CSHH 2012 had significantly higher irrigation water use efficiency (IWUE) and nitrogen use efficiency (NUE) as well as monetary and energy returns. In case of planting geometries, SCY, IWUE, NUE, monetary and energy gain were higher under 67.5×75 cm. CSHH 2012 recorded significantly highest SCY under 67.5×75 cm (3059 kg/ha). While, HHH 494 recorded highest SCY under 67.5×60 cm (2776 kg/ha). Application of 187.5kg N/ha resulted in higher SCY, IWUE, monetary and energy returns, which were at par with 150kg N/ha and statistically lowest under 112.5kg N/ha. Thus it was concluded that cotton hybrid CSHH 2012 performed best at a planting geometry of 67.5×75 cm and nitrogen level 150 kg N/ha in terms of significantly better productivity, profit and energy returns. While, SCY of HHH 494 was higher under planting geometry of 67.5×60 cm.

Key words: Cotton hybrids, energy returns, monetary returns, nitrogen, seed cotton yield (SCY), spacing

Cotton is known as "King of Fibres" due to its commercial and industrial importance. It plays a vital role in agricultural economy of the country. India has a largest area of 123 lakh ha under cotton with the highest production of 285 lakh bales (Anonymous, 2018a). In Punjab, cotton is grown as a major *kharif* crop in the south western region. It was grown on 2.75 lakh ha, produced 12.59 lakh bales with an average lint yield of 778 kg/ha in 2018-19 (Anonymous, 2018b). Cotton production is more likely to increase with higher yield levels rather than area expansion. Cost effective production of cotton can be achieved by efficient use of improved genotypes/hybrids coupled with suitable agronomic practices such as optimum plant density and precise nutrient management (Brar *et al.,* 2015). Therefore, their agronomic requirements need to be evaluated for given set of environmental and edaphic conditions. Plant geometry is a very important factor for attaining optimum crop growth and higher yield. Improper plant geometry as per hybrid requirement at farmer's field is main reason for poor productivity (Nadeem *et al.*, 2010). Although, all nutrients are the key elements in the higher cotton yield but nitrogen requirements depend on many factors including type of variety/hybrids and plant geometry. Farmers also demand information on cultivar differences in response to location-specific needs. Obviously, the best way to achieve these aims is through the scientific evaluation of cultivars for higher productivity, profitability and energy (Singh *et al.,* 2014; Brar *et al.,* 2018). There is considerable change in energy consumption from animal and human power to tractors, electricity and diesel power. With this significant change in energy use pattern in agriculture, commercial energy requirement is increased. Cotton cultivation is also energy intensive because of its long duration and energy expenses for 3-4 times inter-culture and 2-3 times picking. Excessive and unconscious use of inputs to cotton decreased input use efficiency and monetary returns as well as causes negative effects to both environment and farmers.

Keeping the above facts in mind, present study was carried out to evaluate the yield potential of new *hirsutum* hybrids under different planting geometry and nitrogen levels for achieving higher productivity, also their economic and energy viability in the south-western region of Punjab.

MATERIALS ADN METHODS

A field experiment was conducted during *kharif,* 2016 at Punjab Agricultural University, Regional Research Station, Bathinda which lies in Trans Gangetic agro climatic zone, representing the Indo Gangetic alluvial plains of Punjab (a typical representative of semi-arid south western cotton belt). The soil of the experimental field was loamy sand in texture, slightly alkaline (pH 8.13), EC was 0.157 mmhos/ cm, low in available organic carbon (0.34 %), medium in available P (35.4 kg P_2O_5 /ha) and high in available K (224 K_2O kg/ha). The experiment comprised of two *hirsutum* hybrids (HHH 494 and CSHH 2012) in main plot, three spacing levels (67.5×60 cm, 67.5×75 cm and 67.5×90 cm) in sub plot and three nitrogen levels i.e. 112.5 kg N/ha (75% of recommended dose of nitrogen: RDN), 150 kg N/ha (100% RDN) and 187.5 kg N/ha (125% RDN) in sub sub plot of split split plot design. Sowing was done by dibbling method on May 02, 2016. Nitrogen was applied in the form of urea in two equal split applications after first irrigation and at the time of initiation of flowering.

Five representative plants were selected in each treatment for recording the data of yield parameters on plant basis. Seed cotton yield of whole plot was recorded from all the three pickings done from the treatment plots and converted to kg/ha. Monetary benefits were calculated on the basis of prevailing market cost of inputs and price of seed cotton. Water applied per irrigation was measured with parshall flume. Irrigation water use efficiency (IWUE) and nitrogen use efficiency (NUE) was worked out by dividing the SCY with total amount of irrigation water and nitrogenous fertilizer applied for the respective parameter. As per recommendation phosphorus was not applied because it has been applied to preceding wheat crop and soil had sufficient amount of potassium.

The energy was calculated based on the energy equivalents of the input and outputs (Table 1). Input energy was divided into direct (human labour, fuel and electricity power) and indirect (chemicals, fertilizers, seeds, water for irrigation and machinery) energies presented in Table 2. Energy use efficiency (energy ratio), energy productivity, specific energy and net energy gain were calculated as given by Mohammadi and Omid, 2010.

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy Productivity (kg/MJ)} = \frac{\text{Seed cotton yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Specific energy (MJ/kg)} = \frac{\text{Energy input (MJ/ha)}}{\text{Seed cotton yield (kg/ha)}}$$

$$\text{Net energy gain (MJ/ha)} = \text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)}$$

The data was subjected to ANOVA to evaluate the differences between treatments and significance of interaction effects and; means were compared using LSD test (p = 0.05).

RESULTS AND DISCUSSION

Hybrids : The tested *hirusutum* hybrids differed significantly for SCY (Table 3 and 4). Significantly higher number of bolls per plant and numerically greater boll weight led to significantly higher SCY of hybrid CSHH 2012 (2817 kg/ha) in comparison to HHH 494 (2468 kg/ha). Similarly, lint yield, seed yield and stack yield was also significantly higher under hybrid CSHH 2012. SCY of CSHH 2012 was higher by 14.1 per cent as compared to HHH 494. However, no significant difference in number of monopods, sympods per plant, boll weight and ginning out turn (GOT). Brar *et al.* (2015) and Brar *et al.* (2018) also reported significant difference in SCY of different hybrids due to improved number of bolls per plant, while other yield attributes were not affected. Further data in Table 5 and 6 revealed that IWUE as well as NUE was significantly higher under CSHH 2012 as compared to HHH 494. Higher use efficiencies under CSHH 2012 were because of significant higher SCY of CSHH 2012 and *vice versa*. Also, higher SCY resulted in higher cost of picking which led to significantly higher cost of cultivation under CSHH 2012 (Rs. 52594/ha). Similarly, higher yield led to significantly higher gross and net returns from

Table 1. Equivalent of input and output energy used in cotton production.

Source of energy (input or output)	Unit	Energy equivalent (MJ/kg or MJ/l)	References
Seed	kg	25.5	Mittal *et al.*, 1985
Human power	hour	1.96	Mani *et al.*, 2007; Esengun *et al.*, 2007
Machinery	hour	62.7	Nabavi-Palesaraei *et al.*, 2014; Singh *et al.*, 2002
Irrigation	Cubic meter	0.63	Yaldiz *et al.*, 1993
Chemical	kg or litre	120	*Mandal et al., 2002; Canakci et al., 2005*
Diesel	litre	56.31	Mittal *et al.*, 1985; Singh *et al.*, 2002
Nitrogen	kg	60.6	Mandal *et al.*, 2002; Mani *et al.*, 2007; Esengun *et al.*, 2007
Phosphorus (P_2O_5)	kg	11.1	Mittal *et al.*, 1985
Potassium (K_2O)	kg	6.7	Mittal *et al.*, 1985; Esengun *et al.*, 2007
Zinc sulphate	kg	20.9	Mittal *et al.*, 1985
Cotton seed	kg	25	Mittal *et al.*, 1985
Lint	kg	11.8	Mittal *et al.*, 1985
Stack	kg	12.5	*Ozkan et al., 2004 a, b; Devasenapathy et al., 2009*

Table 2. Amounts of direct and indirect inputs energy consumption in cotton production.

Treatments	Direct energy input (MJ/ha)	Indirect energy input (MJ/ha)	Total energy input (MJ/ha)
Hybrids			
HHH 494	5202	13292	18494
CSHH 2012	5316	13292	18608
Spacing levels			
67.5 × 60 cm	5336	13325	18661
67.5 × 75 cm	5309	13292	18602
67.5 × 90 cm	5131	13260	18391
N levels			
112.5 kg/ha	5134	11020	16154
150 kg/ha	5316	13292	18608
187.5 kg/ha	5326	15565	20891

CSHH 2012 as compared to HHH 494. Net return under CSHH 2012 was higher by Rs. 14340/ha over HHH 494. Statistically improved B:C ratio (1.50) owing to significantly improved net returns again indicated superiority of CSHH 2012 over HHH 494 (B:C ratio 1.28).

In case of energy analysis, total input energy used in various farm operations especially picking was also significantly higher under hybrid CSHH 2012. Similarly, total energy output and net energy gain were also significantly higher under CSHH 2012 than HHH 494. Total energy production and net energy gain was 98382 and 79774 MJ/ha under hybrid CSHH 2012 and; 87699 and 69204 MJ/ha under HHH 494, respectively. Being high yielding hybrid CSHH 2012 was more efficient and had significantly higher energy use efficiency (5.30) and energy productivity (0.151 kg SCY/MJ). Whereas CSHH 2012 also has lowest specific energy (10.2 MJ/kg SCY), which means it requires less energy input for each kg seed cotton production. Brar *et al.* (2018) also reported energy

Table 3. Growth contributing characters of *hirsutum* hybrids under different spacing and N levels

Treatments	Plant Height (cm)	Monopods/ plant	Sympods/ plant	Bolls/ plant	Boll weight (g)	Plant Stand /ha
Hybrids						
HHH 494	143.0	1.39	19.5	39.5	3.74	17946
CSHH 2012	155.7	1.50	20.4	46.0	3.83	18814
LSD (p=0.05)	NS	NS	NS	3.5	NS	NS
CV (%)	8.46	8.66	6.61	7.04	8.19	6.15
Spacing levels						
67.5 × 60 cm	156.3	1.28	17.3	36.8	3.54	21431
67.5 × 75 cm	148.6	1.46	21.0	44.8	3.88	18081
67.5 × 90 cm	143.1	1.59	21.6	46.7	3.92	15628
LSD (p=0.05)	8.47	0.09	1.9	4.0	0.18	1171
CV (%)	7.38	8.45	12.44	12.12	6.15	8.29
N levels						
112.5 kg/ha	142.3	1.33	18.1	37.4	3.63	18146
150 kg/ha	148.8	1.46	20.6	44.6	3.84	18505
187.5 kg/ha	157.0	1.53	21.2	46.3	3.88	18489
LSD (p=0.05)	4.60	0.12	1.0	3.6	0.18	NS
CV (%)	4.48	12.39	7.61	12.10	6.90	6.18

Table 4. Yield and yield contributing characters of *hirsutum* hybrids under different spacing and N levels

Treatments	Seed cotton yield (kg/ha)	Lint yield (kg/ha)	Cotton seed yield (kg/ha)	Ginning outturn (%)	Stack yield (kg/ha)
Hybrids					
HHH 494	2468	839	1623	34.0	5957
CSHH 2012	2817	971	1839	34.4	6550
LSD (p=0.05)	261	100	205	NS	373
CV (%)	8.43	9.44	10.13	5.83	5.09
Spacing levels					
67.5 × 60 cm	2699	917	1775	33.9	6654
67.5 × 75 cm	2798	966	1826	34.4	6322
67.5 × 90 cm	2430	833	1591	34.2	5784
LSD (p=0.05)	187	72	125	NS	520
CV (%)	9.20	10.35	9.43	4.01	10.81
N levels					
112.5 kg/ha	2258	770	1483	33.9	5816
150 kg/ha	2819	966	1846	34.2	6338
187.5 kg/ha	2851	980	1864	34.4	6605
LSD (p=0.05)	139	52	98	NS	344
CV (%)	7.67	8.34	8.27	4.48	8.01

productivity ratio of 0.066-0.081 and specific energy of 12.7-15.3 for different cotton genotypes.

Spacing : Perusal of data in Table 3 revealed that except plant height, all growth and yield attributes *i.e.* monopods/plant, sympods / plant, bolls/plant and boll weight were significantly higher under wider planting geometry 67.5×90 cm followed by 67.5×75 cm and significantly least values were recorded under planting geometry of 76.5×60 cm. SCY was significantly higher under 67.5×75 cm and 67.5×60 cm and; both were significantly better over 67.5×90 cm. Further under more wide planting geometry of 67.5×90 cm, the plant density is decreased which significantly decreased the SCY. Affect of better growth and higher yield attributed under wider planting geometries was nullified by lower plant density (Brar *et al.,* 2018). Planting geometry of 67.5×75 cm and 67.5×60 cm recorded significantly higher SCY (2798 and 2699 kg/ha) by 15.1 and 11.1 per cent, respectively over 67.5×90 cm (2430 kg/ha). Similarly, lint yield, seed yield and stack yield was also higher under 67.5×75 cm and 67.5×60 cm and; significantly least under 67.5×90 cm.

Further perusal of data in Table 5 reveals that IWUE and NUE were significantly higher under planting geometries of 67.5×75 cm and 67.5×60 cm as compared to that of 67.5×90 cm. This is because of higher SCY under 67.5×75 cm and 67.5×60 cm (Table 5). Monetary parameters varied with varying seed cotton yield and lower cost of cultivation was recorded under 67.5 × 90 cm. Gross returns, net returns as well as B:C ratio were significantly higher under planting geometry of 67.5×75 cm and 67.5×60 cm because of significantly higher seed cotton yield under these geometries. Cotton sown under 67.5×75 cm consumed higher energy followed by 67.5×60 cm as compared to that in

67.5 × 90 cm. Total energy production as well as net energy gain were recorded significantly higher under 67.5×75 cm and 67.5×60 cm. Net energy gain was 77962 and 78130 MJ/ha under 67.5×75 cm and 67.5×60 cm, respectively, where as it was 67376 MJ/ha under 67.5 × 90 cm. The higher energy use efficiency and energy productivity were also recorded under 67.5×75 cm and 67.5×60 cm compared to that of under 67.5 × 90 cm. However, specific energy was found lower under 67.5 × 75 cm.

Nitrogen : The results indicated that various nitrogen levels varied significantly for growth and yield attributes (Table 3 and 4). Values for monopods, sympods, bolls per plant and boll weight were significantly higher under 187.5 kgN/ha and statistically at par under 150 kgN/ha and significantly least under 112.5 kgN/ha. There was a significant improvement in SCY when the N level was increased from 112.5 kgN/ha to 150 kgN/ha. It was observed that further increase in nitrogen level from 150 kgN/ha to 187.5 kgN/ha showed no significant increase in SCY. An increase of 24.8 and 26.3 per cent in SCY was observed at N levels of 150 kg and 187.5 kgN/ha, respectively over that of 112.5 kgN/ha. Similar results were observed by Rawal *et al.,* (2015) and Brar *et al.* (2018). Lint, seed and stack yield were also following similar trend as seed cotton yield. However, ginning out turn was found non-significant among the nitrogen levels. Singh (2015) also reported similar results.

Data presented in Table 5 reveals that IWUE was significantly higher under 150 kg and 187.5 kg N/ha and; both were significantly better over 112.5 kgN/ha for IWUE. However, NUE was significantly higher under lowest nitrogen level

Table 5. Monetary and energy analysis of different cotton hybrids under different spacings and N levels

Treatments	Irrigation water use efficiency (kg/ha/cm)	Nitrogen use efficiency (kg/N/kg)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Hybrids						
HHH 494	58.75	16.88	50495	115975	65480	1.28
CSHH 2012	67.08	19.17	52594	132415	79820	1.50
LSD (p=0.05)	6.20	1.59	1563	12258	10690	0.15
CV (%)	8.42	7.56	2.59	8.43	12.57	9.71
Spacing levels						
67.5 × 60 cm	64.25	18.36	51881	126830	74949	1.43
67.5 × 75 cm	66.63	19.09	52480	131523	79043	1.49
67.5 × 90 cm	57.87	16.62	50273	114231	63959	1.25
LSD (p=0.05)	4.45	1.20	1121	8784	7662	0.11
CV (%)	9.20	8.65	2.83	9.20	13.72	10.95
N levels						
112.5 kg/ha	53.75	20.07	48997	106112	57116	1.15
150 kg/ha	67.11	18.79	52603	132482	79879	1.50
187.5 kg/ha	67.88	15.20	53035	133990	80955	1.51
LSD (p=0.05)	3.32	0.98	837	6553	5717	0.08
CV (%)	7.67	7.89	2.36	7.67	11.44	8.75

Table 6. Monetary and energy analysis of different cotton hybrids under different spacings and N levels

Treatments	Total energy input (MJ/ha)	Total energy production (MJ/ha)	Net energy gain (MJ/ha)	Energy use efficiency (ratio)	Energy productivity (kg SCY/MJ)	Specific energy (MJ/kg SCY)
Hybrids						
HHH 494	18494	87699	69204	4.75	0.134	11.6
CSHH 2012	18608	98382	79774	5.30	0.151	10.2
LSD (p=0.05)	98	7311	7239	0.36	0.013	1.3
CV (%)	0.45	6.71	8.30	6.19	7.81	10.28
Spacing levels						
67.5 × 60 cm	18661	96790	78130	5.19	0.145	10.6
67.5 × 75 cm	18602	96564	77962	5.21	0.150	10.3
67.5 × 90 cm	18391	85767	67376	4.67	0.132	11.9
LSD (p=0.05)	61	5351	5299	0.27	0.011	0.8
CV (%)	0.43	7.48	9.25	7.10	10.03	8.98
N levels						
112.5 kg/ha	16154	82504	66350	5.10	0.140	11.0
150 kg/ha	18608	97171	78563	5.22	0.151	10.2
187.5 kg/ha	20891	99446	78555	4.76	0.136	11.5
LSD (p=0.05)	44	3915	3878	0.21	0.007	0.5
CV (%)	0.35	6.12	7.57	6.07	7.33	7.02

of 112.5 kg N/ha and decreased significantly with each increase in nitrogen level, because of the failure of proportional increase in SCY with each increase in nitrogen levels. Monetary parameters also followed similar trend as SCY. Cost of cultivation was significantly higher under 187.5 kgN/ha which was at par with 150 kgN/ha and statistically least in 112.5 kgN/ha. Cost of cultivation mainly varies with cost of fertilizers and picking. Significantly highest net returns (Rs. 80955/ha) and B:C ratio (1.51) were recorded under 187.5 kgN/ha which were statistically at par with net returns (Rs. 79879/ha) and B:C ratio (1.50) under 150 kgN/ha. While, statistically the least net returns (Rs. 57116/ha) and B:C ratio (1.15) was observed under 112.5 kgN/ha.

Table 7. Two way table for SCY (kg/ha) between *hirsutum* hybrids and spacing.

Treatments	S_1-67.5 ×60 cm	S_2-67.5 ×75 cm	S_3-67.5 ×90 cm	**Mean**
HHH 494	2776	2537	2089	**2468**
CSHH 2012	2621	3059	2772	**2817**
Mean	**2699**	**2798**	**2430**	
LSD (p=0.05)	264			

In case of energy analysis, total input energy consumption increased significantly with each increase in nitrogen level. Total energy production and net energy gain also increased with increase in N levels from 112.5 kgN/ha to 150 kgN/ha, but increase in N level from 150 kgN/ha to 187.5 kgN/ha did not increase energy production and net energy gain significantly. While, energy use efficiency was statistically at par in 112.5 kgN/ha and 150 kgN/ha and were decreased significantly with further increase in nitrogen level to 187.5 kgN/ha. Energy productivity was significantly higher and specific energy was significantly lowest under 150 kgN/ha compared to 112.5 kgN/ha and 187.5 kgN/ha.

Interaction results : Interaction among the hybrids, spacing and fertilizers for SCY was found non-significant. While, interaction among the hybrids and spacing was found significant (Table 7). CSHH 2012 recorded significantly highest SCY (3059 kg/ha) at a spacing level of 67.5×75 cm and showed significant yield reduction by either increase or decrease in plant spacing. However, HHH 494 recorded highest SCY (2776 kg/ha) at a spacing of 67.5×60 cm and it was statistically at par with 67.5×75 cm. There was significant yield reduction with further increase in plant spacing.

It is concluded that among the hybrids, CSHH 2012 performed significantly better over HHH 494 in terms of SCY, use efficiencies, energy and monetary returns. In case of planting geometries, spacing of 67.5×75 cm was found suitable for these hybrids. Nitrogen level of 150 kg N/ha was best for productivity and profitability. While in case of interaction among the hybrids and planting geometries, hybrid CSHH 2012 produced significantly higher SCY under spacing of 67.5×75 cm and hybrid HHH 494 under spacing of 67.5×60 cm.

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