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Evaluation of agronomic requirements of cotton hybrids for productivity, monetary and energy gain in south western region of Punjab

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ABSTRACT : A field experiment was conducted during *kharif* 2015 at Punjab Agricultural University, Regional Research Station, Bathinda to evaluate the performance of two American cotton hybrids FHH 209 and HSHH 31, against local check LHH 144 in main plot; two levels of spacing (67.5 × 75 and 67.5 × 90 cm) in sub plot and three nitrogen levels (75%, 100% and 125% of recommended dose of nitrogen (RDN)) in the sub sub plots. Hybrid FHH 209 produced significantly higher sympods/plant and bolls/m^2 which contributed to significantly highest lint, seed and seed cotton yield, as well as higher nitrogen and irrigation use efficiency as compared to HSHH 31 and LHH 144. Significantly higher monetary and energy returns were also earned from FHH 209. Among different spacing levels, significantly higher plant density as well as bolls/m^2 under spacing of 67.5 × 75 cm resulted in significantly higher seed cotton yield, input use efficiencies, economic and energy returns as compared to 67.5 × 90 cm. Nitrogen levels of 100 and (125% RDN) were statistically *at par* with each other and both were resulted in significantly higher seed cotton yield, monetary returns and net energy gain as compared to 75 per cent RDN. Thus it was concluded that cotton hybrid FHH209 perform significantly better, planting geometry 67.5 × 75 cm and nitrogen level of 150 kg N/ha (100% RDN) were found suitable under south western region of the Punjab.

Key words : Cotton hybrids, economics, energy, planting geometry, nitrogen, seed cotton yield

India has a largest area of 105 lakh ha under cotton with the highest production of 270 lakh bales (170 kg/bale). However, India's average cotton lint productivity is 560 kg/ha which is lower as compared to countries like Australia, China, Brazil, United States (Anonymous, 2017). In Punjab, cotton is the most important commercial crop and predominantly cultivated in south western districts namely Bathinda, Faridkot, Fazilka, Muktsar, Mansa, Sangrur and Ferozepur. There is hardly any scope to increase area under cotton cultivation. Thus, there is need to increase the productivity of cotton per unit area by using new high yielding hybrids coupled with suitable agronomic practices.

Development and release of new varieties/hybrids is a continuous process for replacement of old ones. Growth, development and yield potential of varieties/hybrids is influenced by environmental conditions as well as seasonal management practices. Therefore, their agronomic requirements need to be evaluated for given set of environmental and edaphic conditions. Cost effective production of cotton can be achieved by efficient use of

$$\text{Irrigation water use efficiency (kg/ha cm)} = \frac{\text{Seed cotton yield (kg/ha)}}{\text{Irrigation water (ha cm)}}$$

$$\text{Nitrogen use efficiency (kg/N kg)} = \frac{\text{Seed cotton yield (kg/ha)}}{\text{Nitrogen applied (kg/ha)}}$$

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

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

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

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

improved genotypes/hybrids coupled with suitable agronomic practices such as optimum plant density and precise nutrient management (Brar *et al.,* 2015). Nitrogen is an essential nutrient for cotton that affects plant growth, fruiting and yield, so needs to be supplied in proper quantities. Imbalanced uses of fertilizers may affect vegetative and reproductive growth resulting in decline seed cotton yield (Buttar *et al.,* 2010).

Considerable research studied on monetary returns in agriculture (Singh, 2015; Paslawar *et al.,* 2015; Manjunatha *et al.,* 2010; Biradar et al., 2010 and Shekar, 2012) however, study on energy has been paid relatively little attention. Energy consumption in Indian agriculture has changed with a marked shift from animal and human power to tractors, electricity and diesel power which increases commercial energy requirement. This implies a significant change in energy use pattern in agriculture. Cotton cultivation is also energy intensive. Cotton consumed maximum energy among the wheat, mustard, maize and cluster bean.

Therefore, an attempt was made to examine improved agronomic practices coupled with newly released high yielding cotton hybrid to increase in productivity as well as economically and energy viable production.

A field study was conducted during *kharif,* 2015 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 site was loamy sand in texture, electrical conductivity of 0.15 m mhos, slightly alkaline with pH 8.1, low in available organic carbon (0.19 %), medium in available phosphorus (18.3 kg/ha) and high in available potassium (339.5 kg/ha). The experiment was laid out in a split plot design consisting two new cotton hybrids FHH 209 and HSHH 31, one local check LHH 144 in main plot; two spacing levels *i.e.* 67.5 × 75 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 the sub sub plots and were replicated thrice. Nitrogen was applied through urea in two equal split first after first irrigation and second at the time of initiation of flower.

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 pickings done from the treatment plots and converted to kg/ha. Monetary parameters were calculated on the basis of prevailing market price of inputs and seed cotton.

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.

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)
Seed	kg	25.5
Human power	h	1.96
Machinery	h	62.7
Irrigation	Cubic meter	0.63
Chemical	kg or l	120
Diesel	l	56.31
Nitrogen	kg	60.6
Phosphorus (P_2O_5)	kg	11.1
Potassium (K_2O)	kg	6.7
Zinc sulphate	kg	20.9
Cotton seed	kg	25
Lint	kg	11.8
Stack	kg	12.5

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

Effect of cotton hybrids : Cotton hybrids varied significantly for yield and yield attributed (Table 3). Significantly higher sympods/plant and bolls/m^2 contributed to significantly highest seed cotton yield of hybrid FHH 209 (1463 kg/ ha) as compared to hybrid HSHH 31 (1292 kg/ ha) and check hybrid LHH 144 (1219 kg/ha). Seed cotton yield of hybrid FHH 209 was higher by 13.2 and 20.0 per cent as compared to HSHH 31 and LHH 144, respectively. Similarly lint yield, seed yield and stack yield of hybrid FHH 209 was also higher as compared to HSHH 31 and LHH 144 (Table 4). GOT was found non significant among the hybrids. Singh (2015) and Manjunatha *et al.,* (2010) also reported significant differences for seed cotton yield among tested hybrids due to difference in number of bolls. Irrigation water use efficiency as well as nitrogen use efficiency was significantly higher under FHH 209 as compared to HSHH 31 and LHH 144. This is due to significantly higher seed cotton yield of FHH 209.

Among the monetary parameters (Table 5), cost of cultivation of hybrid FHH 209 (Rs. 39010/ha) was significantly higher as compared to that of HSHH 31 (Rs. 37984/ha) and LHH 144 (Rs. 37549 /ha), as well as gross and net returns earned from hybrid FHH 209 were significantly higher as compared to that of HSHH

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			
FHH 209	4837	13636	**18473**
HSHH 31	4781	13636	**18418**
LHH 144	4758	13636	**18394**
Spacing levels (cm)			
67.5×75	4855	13652	**18508**
67.5×90	4729	13620	**18349**
N levels			
RDN (75%)	4755	11364	**16119**
RDN (100 %)	4806	13636	18442
RDN (125%)	4816	15909	**20724**

Table 3. Growth, yield attributes and seed cotton yield of different cotton hybrids under different spacings and N levels

Treatments	Plant height (cm)	Monopods/ plant	Sympods/ plant	Boll/ m^2	Boll weight (g)	Plant stand / plot	Seed cotton yield (kg/ha)
Hybrids							
FHH 209	122.9	2.99	15.4	63.2	3.27	36.4	1463
HSHH 31	120.4	2.73	14.6	55.6	3.35	35.7	1292
LHH 144	130.3	2.81	14.1	56.2	3.39	36.7	1219
CD (p=0.05)	NS	NS	0.8	5.9	NS	NS	124.6
CV (%)	9.53	8.39	6.18	10.95	4.79	4.87	10.16
SD ±	11.87	0.24	0.91	6.39	0.16	1.77	134.6
Spacing levels (cm)							
67.5×75	126.6	2.62	14.3	61.3	3.23	39.2	1399
67.5×90	122.4	3.06	15.1	55.3	3.44	33.4	1251
CD (p=0.05)	NS	0.12	0.7	4.0	0.18	1.2	113.2
CV (%)	10.36	6.32	7.09	10.22	8.00	4.97	12.83
SD ±	12.90	0.18	1.04	5.96	0.27	1.80	170.0
N levels							
RDN (75%)	116.7	2.36	13.6	54.6	3.19	35.9	1210
RDN (100 %)	127.1	3.07	15.0	59.5	3.40	36.4	1366
RDN (125%)	129.7	3.09	15.5	60.9	3.42	36.6	1398
CD (p=0.05)	7.1	0.20	1.3	2.3	0.18	NS	75.04
CV (%)	8.24	10.11	12.51	5.79	8.01	2.89	8.32
SD ±	10.26	0.29	1.84	3.38	0.27	1.05	110.2

31 and LHH 144 as because of significant higher seed cotton yield of FHH 209. Net returns earned from hybrid FHH 209 were higher by Rs. 6325 and 9007/ha as compared to net returns from HSHH 31 and LHH 144, respectively. As result of higher net returns, B:C ratio was also

significantly improved under hybrid FHH 209 as compared to other hybrids. Similar significant differences among hybrids for monetary parameters were also reported by Singh (2015).

Further perusal of data presented in Table 5, that total input energy used in various farm operations was non significant among the different hybrids and there was little bit differences due to different energy consumption in picking. While, total energy production was higher under FHH 209 than other hybrids. Hybrids FHH 209, HSHH 31 and LHH 144 produced energy of 71738, 64266 and 59929 MJ/ha, respectively. Similarly, net energy gain was also significantly higher under FHH 209 (53265 MJ/ha) as compared to HSHH 31 (45848 MJ/ha) and LHH 144 (41535 MJ/ha). Being high yielding hybrid FHH 209 was more efficient and had significantly higher energy use efficiency (3.91) and energy productivity (0.081 kg SCY/MJ). As well as FHH 209 has lowest specific energy (12.7 MJ/kg SCY), which means it requires less energy input for each kg seed cotton production.

Effect of planting geometry : Among planting geometries (Table 3 and 4), monopods and sympods/plant and boll weight was significantly higher under wider plant spacing (67.5 × 90 cm) as compared to narrow plant spacing (67.5 × 75 cm), but they failed to increase in seed cotton yield. Seed cotton yield, lint yield and seed yield was significantly higher under

Table 4. Effect of different treatments on yield parameters, irrigation water and nitrogen use efficiency

Treatments	Lint yield (kg/ha)	Cotton seed yield (kg/ha)	Ginning outturn (%)	Stack yield (kg/ha)	Irrigation water use efficiency (kg/ha/cm)	Nitrogen use efficiency (kg N/kg)
Hybrids						
FHH 209	501	958	34.3	6701	29.55	10.12
HSHH 31	439	848	34.0	6059	26.10	8.88
LHH 144	416	799	34.2	5607	24.64	8.32
CD (p=0.05)	34	95	NS	602	2.52	0.88
CV (%)	8.00	11.87	4.62	10.62	10.16	10.42
SD ±	36.16	103.07	1.58	650.19	2.72	0.95
Spacing levels (cm)						
67.5×75	477	918	34.1	6517	28.26	9.65
67.5×90	428	819	34.2	5727	25.27	8.57
CD (p=0.05)	44	74	NS	446	2.29	0.78
CV (%)	14.48	12.87	5.45	10.93	12.82	12.88
SD ±	65.52	111.78	1.86	669.13	3.43	1.17
N levels						
RDN (75%)	410	797	33.9	5546	24.45	10.76
RDN (100 %)	469	893	34.3	6192	27.60	9.11
RDN (125%)	478	916	34.2	6630	28.24	7.46
CD (p=0.05)	32	50	NS	267	1.52	0.50
CV (%)	10.22	8.34	5.46	6.35	8.23	7.92
SD ±	46.23	72.45	1.86	388.79	2.20	0.72

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

Treatments	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio	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										
FHH 209	39010	62907	23897	0.609	18473	71738	53265	3.91	0.081	12.7
HSHH 31	37984	55556	17572	0.460	18418	64266	45848	3.51	0.070	14.3
LHH 144	37549	52439	14890	0.391	18394	59929	41535	3.24	0.066	15.3
CD (p=0.05)	749	5358	4610	0.114	NS	5737	5702	0.31	0.008	1.5
CV (%)	2.12	10.16	26.51	25.35	0.34	9.49	13.14	9.40	12.32	11.70
SD ±	809	5788	4980	0.12	62.66	6198.01	6160.38	0.33	0.01	1.65
Spacing levels (cm)										
67.5×75	38705	60151	21446	0.550	18508	69310	50802	3.76	0.077	13.4
67.5×90	37657	53783	16127	0.424	18349	61312	42963	3.35	0.068	14.8
CD (p=0.05)	679	4867	4188	0.098	36	4346	4316	0.24	0.006	1.1
CV (%)	2.67	12.82	33.47	30.25	0.29	9.99	13.82	10.12	12.03	11.65
SD ±	1019	7303	6288	0.15	53.44	6524.57	6479.16	0.36	0.01	1.64
N levels										
RDN (75%)	37282	52049	14767	0.390	16119	59414	43296	3.68	0.076	13.7
RDN (100 %)	38429	58745	20316	0.525	18442	66553	48111	3.61	0.074	13.7
RDN (125%)	38832	60107	21275	0.544	20724	69966	49242	3.38	0.068	15.0
CD (p=0.05)	451	3227	2777	0.066	24	2393	2375	0.13	0.005	0.8
CV (%)	1.72	8.23	21.48	19.82	0.19	5.33	7.36	5.13	9.86	8.25
SD ±	657	4688	4035	0.10	35.01	3481.08	3450.59	0.18	0.01	1.17

67.5 × 75 cm, because of significantly higher plant density as well as significantly higher bolls/m^2 under 67.5 × 75 as compared to 67.5 × 90 cm. Higher plant density under 67.5 × 75 cm led to significantly higher stack yield as compared to under 67.5 × 90 cm. Nehra and Yadav (2012) and Shekar *et al.,* (2012) also reported higher seed cotton yield with higher plant density. Among the efficiencies (Table 4), irrigation water use efficiency and nitrogen use efficiency was higher under 67.5 × 75 than under 67.5 × 90 cm.

Monetary parameters mainly varied with seed cotton yield (Table 5), lower cost of cultivation under 67.5 × 90 cm. while, gross returns and net returns as well as B:C ratio were significantly higher under planting geometry 67.5 × 75 cm because of significantly higher seed cotton yield under this geometry. Cotton sown under 67.5 × 75 cm consumed higher input energy 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. Energy production and net energy gain were 69310 and 50802 MJ/ha, respectively under 67.5 × 75 cm and; 61312 and 42963 MJ/ha, respectively under 67.5 × 90 cm. The higher energy use efficiency and energy productivity were recorded under 67.5 × 75 cm compared to that of under 67.5 × 90 cm. However, specific energy was found lower under 67.5 × 75 cm.

Effect of nitrogen levels : Nitrogen levels also exerted significant effect on growth and seed cotton yield (Table 3). Application of 125 per cent RDN (187.5 kg N/ha) resulted in maximum monopods, sympods/plant, bolls/m^2, boll weight as well as seed cotton yield, which were *at par* with 100 per cent RDN (150 kg N/ha) while statistically least monopods, sympods/plant, bolls/m^2, boll weight and seed cotton yield was recorded under 75 per cent RDN (112.5 kg N/ha). There was a significant improvement in growth, yield and yield attributes when the N level was increased from 75 per cent RDN (112.5 kg N/ha) to 100 per cent RDN (150 kg N/ha) though 100 per cent RDN was *at par* with 125 per cent RDN (187.5 kg N/ha). Seed cotton yield increased by 12.9 and 15.5 per cent at N levels of 100 per cent RDN and 125 per cent RDN, respectively over that of 75 per cent RDN. Significant higher seed cotton yield due to better bolls/plant under elevated levels of nutrients was reported by Bhalerao *et al.,* (2010) and Sunitha *et al.,* (2010). Lint and seed yield were also following similar trend as seed cotton yield (Table 4). However, stack yield increased significantly with each increase in nitrogen level. Singh (2015) and Brar *et al.,* (2015) also reported similar results. Irrigation water use efficiency was also statistically *at par* with among 125 and 100 per cent RDN and both were significantly better over 75 per cent RDN for IWUE. While, nitrogen use efficiency was significantly higher under lowest nitrogen dose of 75 per cent RDN and 2nd highest under 100 per cent RDN and significantly least under 125 per cent RDN.

Further perusal of data presented in Table 5, that monetary parameter also followed similar trend as seed cotton yield. Cost of cultivation was significantly higher under 125 per cent RDN which was *at par* with 100 per cent RDN and statistically least in 75 per cent RDN. Cost of cultivation mainly varies with cost of fertilizers and picking. Significantly highest net returns (Rs. 21275/ha) and B:C ratio (0.54) were recorded under 125 per cent RDN which were statistically *at par* with net returns (Rs. 20316/ ha) and B:C ratio (0.52) under 100 per cent RDN. While, Biradar *et al.,* (2010) reported higher returns with enhanced level of nutrition (150% RD) than 100 per cent recommended level. In case of energy, total input energy consumption as well as total energy production increased significantly with each increase in nitrogen level. Net energy gain was also increased with increase in N levels from 75 to 100 per cent RDN, but increase in N level from 100 to 125 per cent RDN did not increase net energy gain significantly. While, energy use efficiency and energy productivity were statistically *at par* under 75 and 100 per cent of RDN and were decreased significantly with further increase in nitrogen level to 125 per cent RDN. Specific energy was also significantly lower under 75 and 100 per cent of RDN as compared to 125 per cent RDN.

CONCLUSIONS

It is concluded that hybrid FHH209 performed significantly better over hybrid HSHH31 and check LHH144 for yield attributes, seed cotton yield, NUE, IWUE, monetary and energy returns. The recommended planting geometry (67.5 × 75 cm) and nitrogen level (100% RDN: 150 kg N/ha) were found suitable with respect to cotton productivity, IWUE, monetary and energy parameters.

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