



Partial factor and water productivity of FIRB planted transgenic cotton (*Gossypium hirsutum*) under different fertilizer levels

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ABSTRACT

Fertilizer and moisture availability affect various physiological and growth processes and are key factors in controlling productivity and yield of cotton crop. Two-year experiment (*kharif* 2012 and 2013) was conducted to evaluate the effects of different fertilizer levels on growth, yield, water and partial factor productivity of fertilizers of furrow irrigated raised bed (FIRB) planted transgenic cotton in semi-arid region of north-west India. The fertilization treatment was based on different ratios of N, P₂O₅ and K₂O. Four fertilizer treatments were designed including 75%, 100%, 125% and 150% of recommended rates with N 175, P₂O₅ 60 and K₂O 60 kg/ha. Yield components were measured. Partial factor productivity of fertilizer (PFP), water productivity and economics were calculated. Compared to conventional method of sowing, FIRB planted cotton produced significantly higher yield components, viz. sympods and bolls/plant and boll weight. The seed cotton yield of FIRB planted crop increased by 10.3% in 2012 and 11.2% in 2013. This method of sowing also resulted in higher PFP for individual nutrients, i.e. N, P and K as well as for the total nutrients, i.e. N, P and K. It also provided higher water productivity, net benefit and B:C. Non-Bt genotypes did not show any marked difference in terms of yield, WP and PFP of nutrients applied over Bt, however, was better in terms of net benefit and B:C. The PFP decreased with the increase of fertilization rates. With 75% RDF, the PFP_N during the respective two crop seasons was 14.02 and 12.98 kg seed cotton/kg applied N and decreased to 7.05 and 6.98 with 150% RDF. The corresponding values of PFP_{P or K} were 40.90 and 37.88 which decreased to 21.89 and 20.31 kg seed cotton/kg applied P or K. Similarly, the PFP_{N, P and K} was 8.33 and 7.72 and the corresponding values with 150% RDF were 4.45 and 4.41 kg seed cotton per kg applied N, P and K. Under semi-arid conditions, to achieve higher productivity hybrid cotton (*Gossypium hirsutum* L.) be planted under FIRB system fertilized with N-175, P₂O₅-60 and K₂O-60 kg/ha.

Key words: Cotton, Fertilizer levels, FIRB, Partial factor productivity, Water productivity

In north-west India cotton is one of the important cash crops and a fiber crop. Its productivity has increased after the introduction of Bt-cotton which occupies more than 90% of the total area under cotton. However, yields achieved are substantially lower 494 kg lint/ha than the world average of 705 kg lint/ha. This level of productivity is about 1/4 of Australia about 1/3 of Brazil and China (USDA 2016). Its full potential is not being achieved due to various types of stress like water and nutrients and management practices. Yields can be substantially enhanced by adopting high end modern technologies such as optimum supply of nutrients and water, and tillage practices. Potential agronomic advantages of FIRB planting technique include water saving ranging from 18% to 30-50% and nutrients, labour and improve the

physical properties of soil, reduced waterlogging and timely machinery operations due to better surface drainage (Naresh *et al.* 2012). Planting of crops on FIRB, especially wide spaced like cotton has scope to avoid the excess and low water stress (Ali *et al.* 2010) and efficient use of applied fertilizers. Ridge sowing enhanced seed cotton and lint yield over flat bed sowing (Dabhi *et al.* 2014).

The hybrid cotton has the potential to achieve high yields under optimum moisture and nutrient conditions. Optimum and balanced supply of major nutrients is essential for the growth and development of cotton crop. Nitrogen fertilization had significant impacts on plant growth, lint yields and fiber quality of cotton (Sivakumari and Mohan 2009). It's management faces many problems especially the cost, and the negative impacts on both environmental and economic sides. N is an important nutrient which plays vital role in cell division and cell elongation, and promoting growth, preventing shedding of fruiting bodies and higher potentiality in retention of bolls/plant in cotton (Perumal 1999).

Phosphorus is a constituent of cell nuclei, essential for

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cell division and development of meristematic tissue (Russell 2001) and has a well known impact on photosynthesis. It is needed for formation and better development of root system, help plant to combat a variety of climatic and biological stresses. It facilitates the balanced utilization of other nutrients, especially the N. Potassium plays a key role for development and maturation of bolls favouring plant maturity in cotton. It increases the number, size and weight of bolls. It also enhances the water use efficiency and thus plant resistance to drought conditions (Wang *et al.* 2013).

Evaluation of productivity of individual factors especially the nutrients and water is essential for their efficient utilization under semi-arid conditions (Gadhiya *et al.* 2009). Partial factor productivity (PFP) is a useful measure of nutrient use efficiency as it provides an integrative index that quantifies total economic output relative to the utilization of all nutrient resources in the system (Yadav 2003). Economic analysis is necessary to analyse the higher net returns per unit of fertilizer applied and for making recommendation to farmers.

To evaluate the performance of FIRB planted transgenic cotton in terms of partial productivity of applied fertilizers and water, and economics under different fertilizer levels the present study was carried out.

MATERIALS AND METHODS

Field experiment was conducted during two consecutive *kharif* seasons of 2012 and 2013 at the Research Farm, Department of Agronomy, CCS HAU, Hisar (29° 10' N latitude and 75° 46' E longitudes at 215.2 m above MSL). The soil was sandy loam in texture having 56.2% sand, 25.4% silt and 18.4% clay. The bulk density of this soil was 1.46 to 1.54 g/cm³ and has a basic infiltration rate of 5.5 mm/h. It contained 20.8% and 5.9% moisture on weight basis at -0.03 and -1.5 MPa, respectively. Soil was low in OC (0.54%) and N, medium in available P and high in K, and was slightly alkaline (pH 7.40) in reaction. The water table of the field was shallow; fluctuated from 85 to 162 in 2012 and from 64 to 142 cm in 2013 crop season. During the respective two crop seasons the cotton crop was planted on 24 April and 10 May and final picking was done on 12 November and 22 November. Bt and non-Bt cotton of same genotypes under two planting methods, viz. FIRB and conventional in main plots and four fertilizer levels, viz. 75, 100, 125 and 150 % of recommended dose (RDF) in sub plots were evaluated on the same field during both the crop seasons. Under FIRB planting technique, one row of cotton was planted on the top middle of the bed keeping 58 cm plant to plant spacing. The furrows were about 20 cm deep having a 'V' notch type shape. Thus, the total distance between bottoms of two furrows was 70 cm. In conventional method, crop was sown at a spacing of 67.5 cm × 60 cm. The number of plants per unit area was same in both the methods planting.

The RDF was N 175, P 60 and K 60 kg/ha. Full dose of P through SSP and K through MOP was applied at sowing. Nitrogen was top dressed through urea in three equal splits

at sowing, 45 and 80 DAS. All other practices were followed as per recommendations.

During the 2012 and 2013 crop seasons, total rainfall received was 454 and 701 mm and Pan evaporation was 1263 and 1050 mm, respectively. The total water use was estimated by taking into account the soil moisture depletion, effective rainfall, amount of irrigation water applied and the contribution from ground water. On an average, it was 60 cm under FIRB and 63.5 cm under conventional method of sowing. It varied from 60.2 cm with 75% RDF to 64.4 cm with 150% RDF.

The partial factor productivity (PFP) of fertilizers was calculated as final seed cotton yield per unit of applied nutrients. Since the recommended amount of P and K was same, i.e. 60 kg/ha, the values of PFP calculated for P and K was also same. The water productivity (WP) was calculated as seed cotton yield per unit of total water use as crop ET. Economics was calculated as per the prevailing prices of inputs and produce.

RESULTS AND DISCUSSION

Yield

The yield parameters, viz. sympodia and bolls/plant, and boll weight, and consequently the seed cotton yield were significantly higher under FIRB planted cotton than the conventional method of sowing during both the crop seasons (Tables 1 and 2). The final seed cotton yields in the respective two crop seasons were 1837 and 1708 kg/ha under conventional planting which increased to 2027 and 1901 kg/ha under FIRB system. Thus, the two years pooled seed cotton yield increased by 182 kg/ha (Table 2). Under FIRB system of planting, higher initial pick up of seedlings growth increased the number of sympods and reproductive

Table 1 Number of sympods and bolls of cotton under different treatments during 2012, 2013

Treatment	Sympods/plant			Bolls/ plant		
	2012	2013	Pooled	2012	2013	Pooled
<i>Planting methods</i>						
FIRB	20.31	18.25	19.28	36.02	33.93	34.97
Conventional	17.81	15.95	16.88	33.70	31.58	32.64
CD (P=0.05)	1.47	1.53	1.49	1.87	2.03	1.92
<i>Cotton hybrid</i>						
Bt	18.69	16.81	17.75	34.33	32.2	34.97
Non-Bt	19.44	17.39	18.41	35.39	33.31	32.64
CD (P=0.05)	NS	NS	NS	NS	NS	NS
<i>Fertilizer levels</i>						
75% RDF	16.02	14.29	15.16	32.54	30.45	31.50
100% RDF	18.05	16.17	17.11	34.70	32.91	33.81
125% RDF	19.74	17.63	18.69	35.79	33.79	34.79
150% RDF	22.44	20.3	21.37	36.41	33.87	35.14
CD (P=0.05)	1.44	1.43	2.12	1.01	0.90	0.91

Table 2 Boll weight and seed cotton yield under different treatments during 2012, 2013

Treatment	Boll weight, g			Seed cotton yield, kg/ha		
	2012	2013	Pooled	2012	2013	Pooled
<i>Planting methods</i>						
FIRB	3.80	3.59	3.69	2027	1901	2005
Conventional	3.57	3.36	3.46	1837	1708	1823
CD (P=0.05)	0.19	0.21	0.19	37	98	51
<i>Cotton hybrid</i>						
Bt	3.63	3.42	3.52	1935	1794	1939
Non-Bt	3.74	3.52	3.63	1924	1814	1889
CD (P=0.05)	NS	NS	NS	NS	NS	NS
<i>Fertilizer levels</i>						
75% RDF	3.45	3.24	3.34	1840	1708	1832
100% RDF	3.67	3.49	3.58	1946	1811	1929
125% RDF	3.77	3.58	3.68	1961	1843	1943
150% RDF	3.84	3.59	3.71	1970	1855	1952
CD (P=0.05)	0.10	0.09	0.09	18	87	17

parts like squares and bolls/plant. High light interception also reduced the shedding of fruiting parts. Analogous increase in yield of cotton planted under FIRB was also observed by Ali *et al.* (2010) in Pakistan. Similarly, ridge sowing enhanced yield parameters, viz. number of bolls/plant, boll weight and seed cotton and lint yield over flat bed sowing in Gujarat (Dabhi *et al.* 2014)

Since there was no damage of boll worms for which Bt hybrids were introduced, Bt and non-Bt during both the crop season did not differ significantly with respect to all the yield attributing parameters as well as the seed cotton yield.

Application of 100% RDF produced significantly more sympods, bolls/plant, boll weight and seed cotton yield as compared to 75% RDF (Tables 1 and 2). Significant increase in number of sympods/plant was recorded with increase in each level of RDF in both the crop seasons, however, the difference between 100 and 125% RDF for pooled number of sympods was not marked. Response of 125% RDF in 2012 season and also pooled was significant in terms of higher bolls/plant over 100% RDF, while in 2013 season, the response of increase in each level of RDF beyond 100% was not noticeable. Increased boll weight may be associated with more dry matter accumulation in the higher fertilization plot. Sawan *et al.* (2006) reported that increase in yield due to increased N application might be because of increased boll numbers and boll size.

Each successive increase of 60 kg N up to 180 kg/ha significantly increased leaf area, biomass production, crop growth rate, boll number and boll weight ultimately resulting in markedly higher seed cotton yields (Sivakumari and Mohan 2009).

Boll weight and boll number are related with appropriate increase in potassium (Wang *et al.* 2013). Remarkable improvements in cotton yield and quality resulting from

potassium input were reported (Kumar and Srivastava 2015, Parmar *et al.* 2010 and Kumar *et al.* 2010).

However, the differences between incremental level of RDF from 100 to 125 and from 125 to 150 % were not found to be significant as also reported by Deshpande *et al.* (2014) and Rawal *et al.* (2015). Cotton, being an indeterminate crop, the positive effect of applied fertilizers can be realized to the level to have the synchronized growth of vegetative and reproductive parts. Beyond this, the positive effect on yield is nullified because of more vegetative growth and less fruiting bodies. Application of 34 kg/ha P was found optimum to maximize the yield parameters and seed cotton yield (Ahmad *et al.* 2009)

Partial factor productivity (PFP) of applied fertilizers

The PFP calculated for individual nutrients, ie. N, P and K as well as for the total nutrients, i.e. N, P and K applied was significantly higher in FIRB planted cotton as compared to its conventional sowing during both the crop seasons (Fig 1). The higher PFP under FIRB planting system was because of higher seed cotton yield. The Bt and non-Bt hybrids did not show any difference in terms of PFP of applied fertilizers because of the similar seed cotton yield of both the hybrids.

The PFP of applied N, P and or K as well as total N, P and K during both the crop seasons was highest with 75% RDF. It decreased significantly with increase in each level

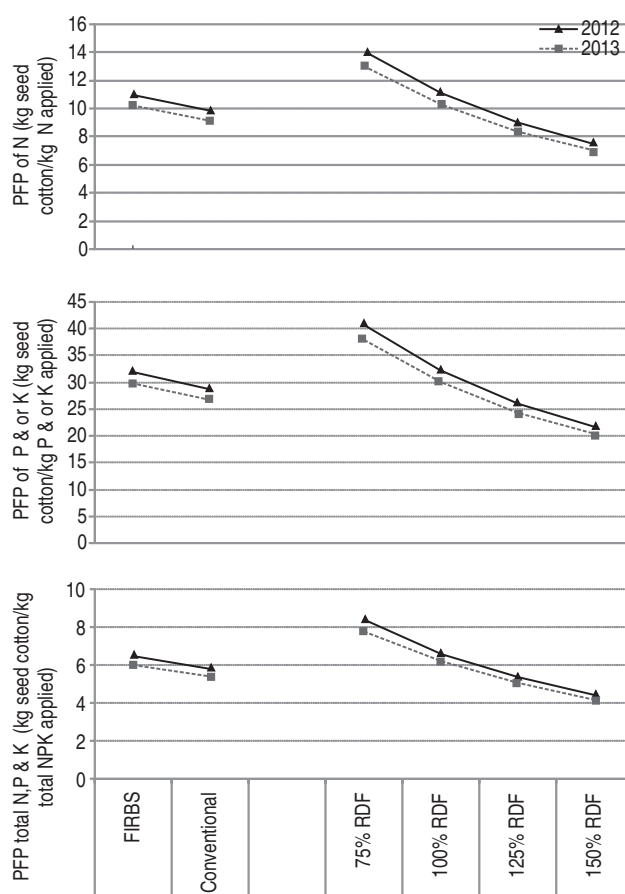


Fig 1 Partial factor productivity (PFP) of fertilizers applied in cotton during 2012 and 2013

Table 3 Economics (₹/ha) of cotton under different treatment during 2012 and 2013

Treatment	2012				2013			
	Gross return	Total cost	Net benefit	B:C	Gross return	Total cost	Net benefit	B:C
<i>Planting methods</i>								
FIRB	84121	74809	9312	1.12	96381	71101	25280	1.36
Conventional	76236	76039	197	1.00	86596	71839	14756	1.21
<i>Cotton hybrid</i>								
Bt	80303	77068	3235	1.04	90956	73007	17948	1.25
Non-Bt	79846	73762	6084	1.08	91970	69795	22175	1.32
<i>Fertilizer levels</i>								
75% RDF	76360	73214	3146	1.04	86596	69230	17366	1.25
100% RDF	80759	74821	5938	1.08	91818	70829	20989	1.30
125% RDF	81382	76156	5226	1.07	93440	72214	21226	1.29
150% RDF	81755	77472	4283	1.06	94049	73540	20509	1.28

of RDF and was lowest with 150% RDF (Fig 1). During the respective crop seasons of 2012 and 2013, with 75% RDF the PFP_N were 14.02 and 12.98, PFP_{P or K} were 40.90 and 37.88 and PFP_{N, P & K} were 8.33 and 7.72 kg seed cotton per kg applied nutrients. The respective values of PFP with 150% RDF were 7.50 and 6.98, 21.98 and 20.31, and 4.45 and 4.14 kg seed cotton per kg applied nutrients. The seed cotton yield beyond 100% RDF was not observed in proportion to the amount of fertilizers applied. Yadav (2003) observed decline in partial productivity for N in cereal based system leading to higher investment in N to maintain higher yields in rice-wheat systems of India (Wu *et al.* 2014) also reported decreased PFP of applied fertilizers with the increase of fertilization rate. Increase in yield enough to pay for its cost per unit of fertilizer applied, its application will not be economical (Singh 2004). Application of a unit fertilizer is economical, if the value of the increase in the crop yield due to the quantity of fertilizer added is greater than the cost of fertilizer used.

Water productivity (WP)

Planting cotton under FIRB achieved higher WP. It was 0.337 and 0.306 under FIRB system, and 0.290 and 0.266 kg seed cotton/m³ of total water use as ET under conventional method during the respective two crop seasons (Fig 2). This was primarily due to lesser amount of total water use and higher seed cotton yield under FIRB system as compared to conventional sowing. Bt achieved almost the same level of WP as that of non-Bt hybrids.

Application of 100 or 125% RDF resulted in equally higher WP over either 75 or 150% RDF levels (Fig 2). Compared to 100 or 125% RDF, decreased seed cotton yield with 75% RDF while relatively more amount of water use by the crop with 150% RDF resulted in lower WP under these fertilizer treatments.

Economics

The net benefit and B:C achieved in FIRB planted crop

were higher as compared to the conventional sowing of cotton during both the seasons. Cultivation of non-Bt hybrid provided relatively higher net benefit and B: C than the Bt due to less cost of seed non-Bt seed. Net benefit in Non Bt cultivation was ₹ 6084 and ₹ 22175 during 2012 and 2013 respectively, whereas in Bt cultivation. Net benefit was ₹ 3235 and ₹ 17948 during 2012 and 2013 respectively. B:C was 1.04 and 1.08 during 2012 in Bt and Non Bt cultivation, respectively. Similarly during 2013 it was 1.25 and 1.32 for Bt and Non-Bt cultivation, respectively. Higher net benefit during 2013 was mainly due to higher market price of cotton during 2013.

Application of 100% RDF resulted in better net returns and B:C than 75% RDF. Increasing the fertilizer levels beyond 100% RDF did not increase the net returns and B:C because additional cost of fertilizer used in 125% and 150% RDF was higher than income obtained in respective treatments compared to 100% RDF during both the crop seasons.

FIRB planted cotton produced higher seed cotton yield, partial factor productivity (PFP) of fertilizers applied, water productivity (WP), net benefit than conventional sowing. Bt and non-Bt achieved the same level of yield, PFP of fertilizers and WP. Application of 100% RDF was found

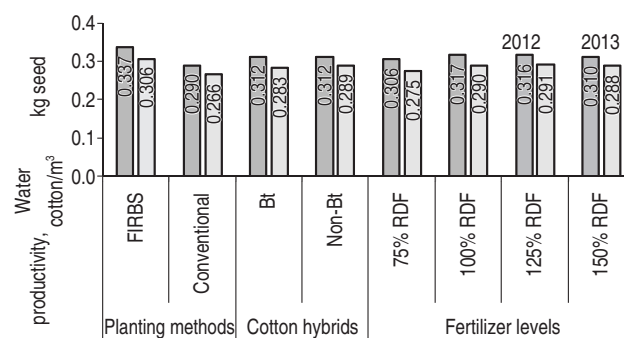


Fig 2 Water productivity of cotton under different treatments during 2012 and 2013

optimum in terms of seed cotton yield, higher WP and net benefit. The PFP was highest with 75% RDF and decreased with increase in fertilizer levels.

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