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Productivity and profitability of cotton–wheat system as influenced by relay intercropping of insect resistant transgenic cotton in bed planted wheat

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ABSTRACT

Cotton (*Gossypium hirsutum* L.) is the leading cash crop being grown across the globe including Pakistan. By the inclusion of insect resistant transgenic cotton (*BT* cotton), the cotton production has mounted many folds in Pakistan. *BT* cotton is mostly grown in Southern Punjab in cotton–wheat cropping system of Pakistan; however there exists a time conflict among wheat harvest and *BT* cotton sowing in this system. Wheat is harvested during late April but the ideal sowing time of *BT* cotton is early-mid March indicating a time conflict of 4–6 weeks which is becoming the main concern leading to wheat exclusion from this system. Intercropping of *BT* cotton in standing wheat is one of the possible options to manage this overlapping period. This two year field study was, therefore, conducted at two locations (Multan, Vehari) to evaluate the economic feasibility of relay intercropping of *BT* cotton through different sowing methods in BT cotton–wheat cropping system. *BT* cotton–wheat cropping systems included in the study were: conventionally tilled cotton (CTC) on fallow land during early and late March, CTC during late April after harvest of flat sown wheat (FSW), bed sown wheat (BSW) + intercropped cotton during early and late March, and ridge sown wheat (RSW) + intercropped cotton during early and late March. Planting cotton in fallow land with conventional tillage during early March had more seed cotton yield; whereas planting in the same way during April after wheat harvest had minimum seed cotton yield. Likewise, FSW had more yield than ridge and bed sown wheat with intercropped *BT* cotton during early or late March. However, the system productivity in terms of net income, benefit: cost ratio and marginal rate of return of BSW + intercropped *BT* cotton during early March was the highest during both years at both locations. However, the system with sole crop of *BT* cotton sown on fallow land during late or early March was the least economical even than the system with CTC during late April after harvest of FSW. In conclusion, BSW + intercropped cotton during early March may be opted to manage the time conflict and improve the economic productivity of *BT* cotton–wheat cropping system without wheat exclusion from the system.

1. Introduction

Cotton–wheat is the leading cropping system of this universe following rice–wheat. Moreover, this is the historic crop production system of north-western plains of the sub-continent, one of the major wheat producing regions of the world, having esteemed place in the agricultural growth of this region (Mayee et al., 2008). This system not only guarantees the food and fiber demand of ever rising population, but it is also a big source of foreign exchange income mainly for under developed countries like Pakistan (Javed et al., 2009). However, cotton crop in this system is heavily infested with variety of sucking and chewing insect pests causing about 30–40% yield reduction (Men et al., 2003; Abro et al., 2004). For instance, only in Pakistan, farmers are using US$300 million worth of pesticides annually, out of which more than 75% is used on cotton to control pests, especially bollworms (Rao, 2007).

Therefore, to tackle the problem of insect pest infestation in cotton, transgenically tailored cotton (*BT* cotton, which expresses insecticidal protein derived from *Bacillus thuringiensis* Berliner)

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Table 1
Physico-chemical properties of the soil of experimental sites before sowing and after harvesting.

Determination	Unit	Multan			Vehari		
		2011	2012	2013	2011	2012	2013
Physical analysis							
Sand	%	28.40	28.40	27.85	28.50	28.70	28.90
Silt	%	51.70	51.65	52.40	50.60	50.50	50.55
Clay	%	19.90	19.95	19.75	20.90	20.80	21.65
Textural class		Silty clay loam			Clay loam		
Chemical analysis							
pH		8.60	8.80	8.55	8.40	8.20	8.35
EC	dS m^{-1}	3.23	3.24	3.20	2.85	3.06	2.97
Organic matter	%	0.68	0.79	0.75	0.69	0.73	0.76
Total nitrogen	%	0.05	0.07	0.07	0.06	0.07	0.08
Available phosphorus	ppm	4.85	5.97	6.83	4.98	6.12	7.20
Available potassium	ppm	332.00	310.00	319.00	300.00	325.00	333.00

was launched as a safe and valuable tool to control cotton pests, bollworms in particular. Hence the frequency of sprays on cotton crop has been declined markedly by adding of *BT* cotton in this system (Men et al., 2003). Hence, *BT* cotton adopting farmers attained pesticide reductions of about 40% with yield gains of 30–40% (Sadashivappa and Qaim, 2009). Similarly some other benefits like dramatic cut in use of conventional and broad-spectrum insecticides, improved productivity, target pest specificity, reduced production costs and compatibility with other biological control agents are tied with transgenic crops like *BT* cotton.

BT cotton is gaining popularity among farmers owing to better yield and less use of pesticides (Abdullah, 2010). But this increase in yield is associated with its long growing period in Pakistan, which enforces the growers to plant *BT* cotton during early March. Hence, after the addition of *BT* cotton in cotton–wheat cropping system; wheat is being evaded from this system due to an overlapping time of about 30–45 days between wheat harvest and sowing of cotton. Wheat cultivation is being reduced in South Punjab as majority of the farmers are shifted towards *BT* cotton cultivation in early March to get its maximum production potential. Early sown cotton initiate its reproductive growth earlier and produce more blooms earlier in the year to set more bolls utilizing the beneficial rains and sunlight that typically occur in June and July (Pettigrew, 2002). Meanwhile, about 70% of wheat growers are shifted towards *BT* cotton production (Sabir et al., 2011).

This situation created some serious concerns about future food supply to the Pakistani residents as over 50% of total wheat production comes from this region. In this situation, some management alternatives are needed to get rid of the time conflict between wheat and cotton in this system. Cotton can be intercropped in standing wheat during early or late March by growing cotton in furrows and wheat on ridges or beds. The seedling phase of cotton and the reproductive phase of wheat overlap over a period of approximately 6–7 weeks between the sowing of cotton and harvest of wheat and immediately after the harvest of cotton at the end of October, wheat is sown again (Zhang et al., 2007). Growing of crops on beds and furrows increased yield due to better nutrient management, efficient irrigation and reduced risk of lodging (Sayre and Ramos, 1997; Anwar et al., 2003; Khan et al., 2012a). Bed planting has also been found to show improved water distribution and efficiency, fertilizer use efficiency, reduced weed infestation and lodging (Hobbs and Gupta, 2003).

Yield advantages from intercropping are often attributed to complementation between component crops in the mixture, resulting in a better total use of resources when growing together rather than separately (Khan et al., 2012b). Intercrops reduced yield of cotton crop by 8–31% however total crop productivity and net return per unit area were greater in intercropping than sole cropping (Khan et al., 2001). In eastern Zambia, cotton is intercropped with groundnut (Waterworth, 1994); while in Egypt cotton is intercropped with basil to suppress pests (Schader et al., 2005). In the United States and China, relay intercropping of cotton with winter and spring crops is used to conserve and enhance natural enemies of cotton aphid (Parajulee et al., 1997; Xia et al., 1998).

To best of our knowledge, no study has been conducted to evaluate the system productivity of BT cotton intercropping in ridge or bed sown wheat to evade the wheat exclusion from cotton–wheat cropping system. It was hypothesized that *BT* cotton intercropped in wheat either sown on ridges or beds may eliminate time conflict between wheat harvest and sowing of cotton, and can improve system productivity of *BT* cotton–wheat system. This two-year study was, therefore, conducted at two locations to evaluate the role of intercropped *BT* cotton in improving system productivity of *BT* cotton–wheat cropping system without wheat exclusion from the system.

2. Materials and methods

2.1. Experimental site description

This two-year field trial was conducted during 2011–12 and 2012–13 at farmer's field in district Vehari (71.44°E, 29.36°N and altitude of 135 m), Pakistan and Agronomic Research Farm, Bahauddin Zakariya University, Multan, Pakistan (71.50°E, 30.26°N and altitude of 123 m). The climate of both locations was subtropical to semi-arid and soil was clay loam at Vehari and silty clay loam in nature at Multan location. The whole physico-chemical analysis of soil at both locations was done each year, before sowing and after harvesting of the crop, as given in Table 1. Weather data of both years of experiment at both locations are given in Table 2.

2.2. Experimental details

BT cotton genotype MNH-886 and wheat cultivar Punjab-2011 was used as experimental material; and seeds of cotton and wheat were purchased from Punjab Seed Corporation, Khanewal, Pakistan. Treatments included in the study were: Conventional tilled cotton (CTC) on fallow land during early and late March, CTC during late April after harvest of flat sown wheat (FSW), bed sown wheat (BSW) + cotton intercropping during early and late March on both sides of beds, and ridge sown wheat (RSW) + cotton intercropping during early and late March in furrows. Experiment was laid out according to randomized complete block design (RCBD) with split plot arrangement by keeping locations and cropping systems in main and sub plots, respectively. Experiment was replicated three times with a net plot size of 3.0 m × 5.0 m for both cotton and wheat crops; whereas the gross plot size was 3.0 m × 7.0 m for both crops.