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RELAY CROPPING OF COTTON IN STANDING WHEAT: AN INNOVATIVE APPROACH FOR ENHANCING THE PRODUCTIVITY AND INCOME OF SMALL FARM

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ABSTRACT

The increasing trend of sowing early Bt cotton as mono crop has reduced the area under wheat crop that leads to decrease of output of per unit area. The experiments were carried out in the same field for two consecutive years during 2012-13 and 2013-14 on wheat-cotton with different relay/intercropping system. Wheat was sown in strips in November and harvested in April of the next year, while cotton was sown in the interspersed space of wheat crop in early March and harvested before the next wheat sowing in November. There were six different planting systems of wheat and cotton i.e. P_1 (wheat 6 rows strips between 150 cm apart ridges + cotton on ridges-single row), P_2 (wheat 6 rows strips between 150 cm apart ridges + cotton on ridges double row), P_3 (Wheat 2 rows strips between 75 cm apart ridges + cotton on ridges single row), P_4 (wheat in 3 rows strips on 75 cm wide beds and cotton dibbling on both sides of beds, P_5 (wheat after cotton as alone crops) and P_6 (Bt-cotton alone early on beds) were used in the experiment. The experiments were laid out in randomized complete blocks design and data regarding crop productivity and profitability of mono and intercrops were collected. The treatment P_2 (6:2) gave 38% higher income and produce maximum BCR (1.92) than early sown alone Bt cotton and proved very successful for relay cropping of cotton in standing wheat crop as wheat yield was not reduced and additional cotton produce was obtained normally.

Key words: relay cotton in wheat, grain yield, lint yield, resource use efficiency, income.

INTRODUCTION

The rapid growth of population is one of the major factors of food shortage in most of the Asian and African countries. One of the possible approaches to tackle this issue would be the maximum utilization of limited agricultural land resources through multiple cropping to increase productivity per unit area of available land (Seran et al., 2010; Khan et al., 2014). Intercropping offers potential benefits relative to monoculture by increasing yield through the effective use of resources, including water, nutrients, solar energy (Nasri et al., 2014). Most importantly, food security can be achieved (Ouma and Jeruto, 2010), which is essential since wheat is the breadbasket of much of the Asian Subcontinent (Hossain and Teixeira da Silva, 2013). In developing countries, intercropping is superior to monocropping in terms of farm income, which is key motivation for farmers. Intercropping is an advanced agronomic technique that allows two or more crops to yield from the same area of land. Better utilization of resources and reduced weed competition minimize the risk of food shortages by enhancing yield stability. Since wheat is the most important cereal around the world and is most suitable for intercropping (Aziz et al., 2015).

Cotton is known as "White Gold". It is one of the most important cash crops of Pakistan contributing major source of foreign exchange earnings. Pakistan is the 4th largest consumer of cotton in the world. According to a rough estimate almost 26% of Pakistani farmers grow cotton and cotton crop is cultivated on an area of 2806 thousand hectares, the production stood at 12.8 million bales (Anonymous, 2014). In the cotton producing region intercrop cotton (*Gossypium*

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hirsutum L.) and winter wheat (*Triticum aestivum* L.) was started because of the need to increase household income by production of the cash crop cotton, while having to continue the production of wheat as a major staple food (Zhang and Li, 2003).

Relay intercropping is a way to produce two crops in one field in the same season when the temperature requirements are too high to allow the second crop to be sown after the first crop is harvested. The second crop is inter-sown in the first crop, commencing development and early growth before the first crop is harvested (Zhang, 2007). The perception of wheat yield reduction due to space left for inter crop loses its weight when the wheat crop exploits the advantage of border effect of strip system planting geometry. It has been found that the number of border rows is a major factor in determining the advantage of wheat productivity in intercropping systems. The increase in yield of intercropped wheat is not only due to border rows wheat but also of inner rows in the wheat/maize intercropping systems (Li et al., 2001b).

The intercropping systems are characterized by differences in production and competitive relationships among cotton and wheat. Thus the productivity and resource use efficiencies of cotton - wheat intercropping can be improved by modifying the conventional management practices and by system optimization (Midmore et al., 1988). It has been suggested that the intercropping systems increase farmers' income under a wide range of wheat and cotton prices.

Keeping in view the sustainability of cotton - wheat cropping system**,** the adoption of *Bacillus thuringiensis* (Bt) cotton cultivars have strongly contributed to a decrease in the use of pesticides and as a consequence increased the profitability, and the ecological safety of cotton production by smallholder farmers (Huang et al., 2002). However on the other hand, with the introduction of Bt cotton in cotton-wheat cropping system the area under wheat is reducing due to early sown crop which is a threat to food security because Bt transgenic cotton is widely grown in the cotton growing areas of Sindh and Punjab and the area expanded to almost 100% in Sindh and 80% in Punjab (Ali et al., 2010), therefore present study is designed to adjust the Bt cotton crop in standing wheat as relay crop and aimed at analyzing productivity and resource use efficiency of cotton wheat relay intercropping systems. To observe the overall profit in intercrops system compared to those of monocultures of wheat and cotton in terms of yield and yield components at field level.

MATERIAL AND METHODS

Field experiments were conducted at Agronomic Research Station, Bahawalpur during 2012-2014 to check the different relay/intercropping systems of wheat (*Triticum aestivum* L.) and cotton (*Gossypium hirsutum* L.). The experiments were comprised of treatments as P_1 (wheat 6 rows strips between 150 cm apart ridges + dibbling 1 row of cotton on ridges), P_2 (wheat 6 rows strips between 150 cm apart ridges + dibbling 2 rows of cotton on ridges), P_3 (wheat 2 rows strips between 75 cm apart ridges + single row of cotton on ridges), P_4 (wheat in 3 rows strips on 75 cm wide beds and cotton dibbling on both sides of beds, P_5 (wheat after cotton alone) and P_6 (early Bt-cotton alone on beds). Distance between rows was 22.5 cm in wheat and 75 cm in cotton monoculture. The treatments were arranged in randomized complete blocks design with a plot size of 6 x 8 m. The wheat variety Meraj-08 was planted on 25.11.2012 and 07.12.2013 and was fertilized as 120-100-60 NPK kg ha^{-1}. The cotton variety MNH-886 was planted on 15.03.2013 and 20.03.2014 in standing wheat crop and was fertilized as 150-60-60 NPK kg ha^{-1} after wheat crop. It is further incorporated that all the agronomic practices like seed rate, control of weeds and plant protection measures for both crops were kept normal. Data regarding, fertile tillers (m^{-2}), grains spike^{-1}, 1000 grain weight (g), grain yield (kg ha^{-1}) of wheat and plant population (plants per hectares), number of bolls per plant, 100-bolls weight and cotton seed yield of were recorded using the standard methods during both crop cycles. The meteorological data of two crop seasons is given in Table 1.

Table 1. Monthly mean of rainfall (mm), relative humidity (%), and maximum and minimum temperature (°C) at the experimental site during 2012-13 and 2013-14 crop seasons*

Month	Rainfall (mm)		Relative humidity (%)		Temperature (°C)			
					Maximum		Minimum	
	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
November	30.6	0.0	86.1	74.3	27.5	24.4	8.9	14.8
December	7.2	0.0	85.8	75.3	26.9	12.8	5.3	7.1
January	1.0	0.0	85.6	71.6	24.8	15.2	2.0	7.9
February	38.0	11.0	75.1	73.4	21.6	18.2	6.4	10.6
March	6.0	4.0	73.1	73.9	27.5	22.1	14.2	14.0
April	0.0	4.0	75.2	74.7	32.9	32.5	20.8	21.6
May	0.0	14.0	73.6	74.6	41.4	39.7	24.5	24.2
June	33.0	0.0	74.7	74.0	43.3	44.8	26.3	27.0
July	3.0	20.0	74.6	76.7	43.2	43.3	32.1	26.5
August	8.0	0.0	76.8	74.9	47.6	39.5	24.0	28.4
September	0.0	5.0	75.0	73.8	34.9	35.7	23.8	24.3
October	0.0	4.0	73.1	76.2	34.4	32.5	23.9	22.0

*Source: Cotton Research Station, Bahawalpur and AZRI, Bahawalpur, Pakistan

Statistical analysis

The data were collected and analyzed statistically by using Fisher's analysis of variance technique and least significant difference (LSD) test at 5% probability level was applied to compare the treatments means (Steel et al., 1997).

RESULTS AND DISCUSSION

Grain yield components and yield of wheat

A perusal of data on fertile tillers of wheat showed that maximum number of tillers (415 m^{-2}) were produced by P_5 treatment (wheat after cotton) however, these were statistically at par with those of P_1 (402 m^{-2}) and P_2 (405 m^{-2}) as depicted in Table 2. It was revealed that planting of wheat on modified field conditions i.e. in wider strips, did not affect tillering behavior of wheat crop indicating no adverse effect on economic yield. Thus the productivity and resource use efficiencies of cotton-wheat intercropping can be improved by modifying the conventional management practices and by system optimization (Midmore et al., 1988).

Data on number of grains per spike of wheat showed that maximum grains (55) were produced by P_1 (wheat + dibbling 1 row of cotton on 150 cm apart ridges) however these were statistically at par with those of 51 and 53 produced by P_2 (wheat + dibbling 2 rows of cotton on 150 cm apart ridges) and P_5 (wheat after cotton) as presented in Table 2. The heavier grains with 1000 grain weight of 40.8 g were produced by P_1 (wheat + dibbling 1 row of cotton on 150 cm apart ridges) however these were statistically at par with those of P_5 (40.5 g) and P_2 (40.3 g). The lowest number of grains per spike and 1000 grain weights was recorded in P_3 treatment which may be due to weaker plants and inter plant competition as well as crop grown in furrows that created temporary water logged condition at irrigation. It revealed that planting of wheat on modified field conditions i.e. in wider strips, did not affect grain weight of wheat crop indicating no adverse effect on economic yield. Lesoing and Francis (1999) reported that corn and grain sorghum border-row yields next to soybean were increased significantly compared with inside rows. Increased yields in border rows of corn were attributed to increases in seed number as well as seed weight.

Table 2. Number of fertile tiller, number of grains per spike, 1000-grain weight of wheat in relay cropping of cotton in wheat

Treatments	Number of fertile tiller (m^{-2})			Number of grains per spike			1000-grain weight (g)		
	2012-2013	2013-2014	Average	2012-2013	2013-2014	Average	2012-2013	2013-2014	Average
P_1: Wheat + dibbling 1 row of cotton on 150 cm apart ridges	404 a	400 a	402 a	52 a	57 a	55 a	40.00 a	41.50 a	40.80 a
P_2: Wheat + dibbling 2 rows of cotton on 150 cm apart ridges	398 a	411 a	405 a	50 a	52 ab	51 ab	39.50 a	40.90 ab	40.30 ab
P_3: Wheat + dibbling 1 row of cotton on 75 cm apart ridges	311 b	325 b	318 b	48 a	45 b	47 b	38.10 a	38.10 b	38.10 b
P_4: Wheat + 75 cm wide beds with cotton on both sides	247 c	247 c	242 c	50 a	54 a	52 a	39.00 a	41.10 a	40.40 ab
P_5: Wheat after cotton	408 a	423 a	415 a	49 a	56 a	53 a	39.70 a	41.30 a	40.50 a
P_6: Early cotton alone on beds	-	-	-	-	-	-	-	-	-
LSD at 5%	49.33	33.23	27.89	6.34	8.69	5.51	3.39	2.94	2.41

Means sharing the same letters in a column do not differ significantly at p 0.05

The 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. Cotton intercropped with a variety of other crops, including cowpea, pigeon pea, rice, groundnut and soybean increased the over all economic return (Padhi et al., 1993; Blaise et al., 2005).

Data on grain yield of wheat revealed that maximum grain yield (4859 kg ha^{-1}) was produced by wheat after cotton rotation (P_5) followed by P_1 (wheat + dibbling 1 row of cotton on 150 cm apart ridges) and P_2 treatment (wheat + dibbling 2 rows of cotton on 150 cm apart ridges) with 4651 and 4534 kg ha^{-1}, respectively. However, these were statistically at par with that of P_5 treatment (Table 3). The data also revealed that planting of wheat on modified field conditions i.e. in wider strips, did not have any adverse effect on economic yield of wheat crop. It may be due to the fact that yields were compensated by border effect. These results are in conformity to those of Li et al. (2001b) and Zhang and Li (2003) who found that yields in border rows of intercropped wheat were significantly higher than those in inner rows, both in wheat/maize and wheat/soybean intercropping systems. The higher wheat yield in border rows can be attributed due to greater light interception and a better acquisition of nutrients in the border rows. Contrary to above, Zhang et al. (2008) stated that the best distribution of light is attained in systems with narrow strips, a high proportion of border rows, and high planting densities of cotton.

In the present study there was maximum decrease in seed cotton yield due to inter crop was recorded in P_4 treatment (wheat + 75 cm wide beds with cotton on both sides) and maximum increase was found in P_2 (wheat + dibbling 2 rows of cotton on 150 cm apart ridges) when compared with cotton sown alone early on the beds. Yang et al. (2010) observed the effect of strip intercropping of wheat and maize with width of 80cm each and observed more root development at most of soil depth and yield advantages in intercropping system compared to sole crop. Banik et al. (2006) also observed the fact that intercropping resulted in increase in total productivity per unit area, improvement in land use efficiency and weed suppression.

Table 3. Grain yield of wheat in relay cropping of cotton in wheat

Treatments	Grain yield (kg ha^{-1})			Yield decrease due to inter crop
	2012-2013	2013-2014	Average	%
P_1: Wheat + dibbling 1 row of cotton on 150 cm apart ridges	4254 ab	5048 a	4651 a	-4.28
P_2: Wheat + dibbling 2 rows of cotton on 150 cm apart ridges	4070 b	4998 a	4534 a	-6.69
P_3: Wheat + dibbling 1 row of cotton on 75 cm apart ridges	3212 c	3398 b	3305 b	-31.98
P_4: Wheat + 75 cm wide beds with cotton on both sides	2018 c	2244 c	2131 c	-56.14
P_5: Wheat after cotton	4333 a	5384 a	4859 a	-
P_6: Cotton alone early on beds	-	-	-	-
LSD at 5%	556	799	514	

Means sharing the same letters in a column do not differ significantly at p 0.05

Plant population, yield components and seed cotton yield

The data presented in Table 4 revealed that plant population per hectare differed significantly in all geometries of planting cotton. Maximum number of plants were recorded in P_5 (wheat after cotton) followed by P_6 (early cotton alone on beds) with the lowest in P_4 (wheat + 75 cm wide beds with cotton on both sides). Data on number of bolls per plant of cotton showed that maximum bolls (125.3) were produced by P_1 (wheat + dibbling 1 row of cotton on 150 cm apart ridges) followed by P_6 (early Bt cotton alone on beds) and P_2 (wheat + dibbling 2 rows of cotton on 150 cm apart ridges) with 82.0 and 78.8 respectively. However, P6 (early Bt cotton alone on beds) and P_2 (wheat + dibbling 2 rows of cotton on 150 cm apart ridges) were statistically at par with those of 51 and 53 produced by P_2 (wheat + dibbling 2 rows of cotton on 150 cm apart ridges) and P_5 (wheat after cotton). The lowest number of bolls per plant of cotton was recorded in P_3, P_4 and P_5 treatments that were mutually at par with each other (Table 4).

Table 4. Plant population, number of bolls per plant and 100 bolls weight in relay cropping of cotton in wheat

Treatments	Plant population (plants ha^{-1})			Number of bolls per plant			100 bolls weight (g)		
	2012-2013	2013-2014	Average	2012-2013	2013-2014	Average	2012-2013	2013-2014	Average
P_1: Wheat + dibbling 1 row of cotton on 150 cm apart ridges	30482 d	16852 d	23667 d	128 a	122.70 a	125.30 a	3.20 a	3.15 a	3.18 a
P_2: Wheat + dibbling 2 rows of cotton on 150 cm apart ridges	44478 c	35186 a	39832 c	82 b	75.70 b	78.80 b	3.18 a	3.09 a	3.14 a
P_3: Wheat + dibbling 1 row of cotton on 75 cm apart ridges	24394 e	22531 b	23463 d	53 c	42.30 c	47.70 c	3.17 a	3.14 a	3.15 a
P_4: Wheat + 75 cm wide beds with cotton on both sides	21858 f	18149 c	20003 e	42 c	40.70 c	41.30 c	3.22 a	3.09 a	3.16 a
P_5: Wheat after cotton	58810 a	35865 a	47338 a	47 c	36.30 c	41.80 c	3.20 a	3.09 a	3.14 a
P_6: Cotton alone early on beds	54362 b	35495 a	44928 b	86 b	78.00 b	82.00 b	3.25 a	3.13 a	3.19 a
LSD at 5%	2218	1074	927	15.13	8.60	9.65	0.29 NS	0.27N S	0.27 NS

Means sharing the same letters in a column do not differ significantly at p 0.05.

It has been revealed that cotton planted on wider row spacing produced more number of bolls per plant that compensated to some extent the lower plant population per unit area and effects on economic yield. The formation of squares, flowers and bolls was delayed in intercropping, compared to monoculture (Zhang, 2007). The delay in cotton development in wheat-cotton relay strip intercropping systems compared to cotton in monoculture is larger and has serious consequences, the yield components such as fruit numbers of cotton in wheat-cotton intercropping were much affected by the developmental delay (Bukovinszky et al., 2004, Zhang, 2007).

An assessment of data presented in Table 4 revealed that heavier bolls with 3.19 g were produced by P_6 (early Bt cotton alone on beds) followed by P_1 (wheat + dibbling 1 row of cotton on 150 cm apart ridges) and P_4 (wheat + cotton dibbling on both sides of 75 cm wide beds with) with 3.18 g and 3.16 g weight per boll and were statistically at par with each other. The lowest boll weight was recorded in P_2, P_3, and P_5 treatments with 3.14, 3.15 and 3.14 g, respectively. It revealed that boll weight was significantly affected by different geometries of planting of cotton indicating a definite contribution towards economic yield. These results are in conformity with those of Lesoing and Francis (1999) who reported that corn and grain sorghum increased yields in border rows of corn were attributed to increases in seed number as well as seed weight.

Data regarding seed cotton yield revealed that maximum seed cotton yield (5083 kg ha^{-1}) was produced by P_6 (early cotton alone on beds) followed by P_2 (wheat + dibbling 2 row of cotton on 150 cm apart ridges) with 4731 kg ha^{-1}. The lowest yields were obtained by P_3, P_4 and P_5 treatments as 2792, 2564 and 2905 kg ha^{-1}, respectively (Table 5).

The lower yields of seed cotton in P_3 treatment were apparently attributed to the fact that the growth of cotton seedlings in intercrops was thus severely suppressed; indicating competitive effects, especially in the 3:1 system. The low yield in P_1 treatment may be due to low plant density that may leads to producing less number of fruits per unit area (Table 5). Similar findings were reported by Zhang (2007) that increasing plant density to obtain more fruits per unit of land is key role in obtaining optimum yields. Another factor that might affect the cotton yield was delay in growth and development during seedling stage due to shading effect of wheat crop.

Table 5. Yield of cotton from relay cropping of cotton in wheat

Treatments	Seed cotton yield (kg ha^{-1})			Yield increase/ decrease over conventional system (P_5)	Yield decrease over Bt cotton alone system (P_6)
	2012-2013	2013-2014	Average	%	%
P_1: Wheat + dibbling 1 row of cotton on 150 cm apart ridges	4196 b	4111 b	4170 c	+30.3	-17.95
P_2: Wheat + dibbling 2 rows of cotton on 150 cm apart ridges	4748 a	4713 a	4731 b	+38.6	-6.91
P_3: Wheat + dibbling 1 row of cotton on 75 cm apart ridges	2822 c	2763 c	2792 de	-4.05	-45.06
P_4: Wheat + 75 cm wide beds with cotton on both sides	2710 c	2418 c	2564 e	-13.3	-49.55
P_5: Cotton after wheat	3176 c	2634 c	2905 d	-	-42.84
P_6: Cotton alone early on beds	5099 a	5066 a	5082 a	+42.8	-
LSD at 5%	559.77	361.15	309.04		

Means sharing the same letters in a column do not differ significantly at p 0.05.

Results of this study are contrary to Zhang (2007) findings regarding the wider space between the rows resulting in radiation loss on the soil and a low linear rate of growth. This was overcome by fact that the cotton genotype used for relay crop was spreading type that covered the whole space left after the harvest of wheat crop enabling the complete interception of radiant light and other resources like nitrogen and water.

Economic analysis

In the present study data of different production system revealed that in P_2 treatment (wheat + 2 rows of cotton on 150 cm apart ridges) highest BCR value (1.92) was recorded with maximum income per hectare of Rs. 237184 per hectares followed by P_1 (wheat + 1 row of cotton on 150 cm apart ridges) with BCR of 1.78 and Rs. 201308 per hectares as net income in comparison with the farmer practice as Bt-cotton alone (P_6) and wheat after cotton (P_5) recording BCR values of 1.68 and 1.46 with net income of Rs. 146916 and 118429 per hectare, respectively (Table 6). To evaluate the economic profitability of wheat-cotton intercropping systems, it is needed to take into account the fluctuation of price ratio between lint and grain. Zhang (2007) also concluded that the developmental delay of cotton was one of the most important factors determining productivity in wheat-cotton intercropping systems.

Table 6. Economic analysis of relay cotton in wheat crop (Average of two years i.e. 2012-13 and 2013-14)

Treatments	Yield (kg ha^{-1})		Gross income (Rs. ha^{-1})				Cost of production (Rs. ha^{-1})			Net income (Rs. ha^{-1})	Benefit cost ratio (BCR)
	Cotton	Wheat	Cotton	Wheat straw	Wheat	Total	Cotton	Wheat	Total		
P_1: Wheat + dibbling 1 row of cotton on 150 cm apart ridges	4170	4651	297113	23255	139530	459898	191008	67582	258590	201308	1.78
P_2: Wheat + dibbling 2 rows of cotton on 150 cm apart ridges	4731	4534	337084	22670	136020	495774	191008	67582	258590	237184	1.92
P_3: Wheat + dibbling 1 row of cotton on 75 cm apart ridges	2792	3305	198954	16525	99150	314629	191008	66593	257601	57028	1.22
P_4: Wheat + 75 cm wide beds with cotton on both sides	2564	2131	182685	10655	63930	257270	191008	66593	257601	-331	1.00
P_5: Cotton after wheat	2905	4859	206969	24295	145755	377019	191008	67582	258590	118429	1.46
P_6: Cotton alone early on beds	5083	-	362140	0		362140	215224	0	215224	146916	1.68

These results of present investigation clearly indicate that despite of depressed yield of intercrop cotton, the overall profitability was enhanced by adopting the relay cropping of cotton in standing wheat with 6:2 (wheat - cotton) row systems (Table 6). These results are in line with those of Wasaya et al. (2013), Banik et al. (2006) and Munir et al. (2004) and they reported that intercropping gave higher economic return than monoculture/sole cropping. According to some researchers, the depressed yield of cotton as intercrop was attributed to the delay in development due to shading effect of wheat crop at early seedling stage. Such constraint was overcome by some agronomic measure such as planting relay crop of cotton on ridges and selection of early maturing cotton genotype. Since a ridge-furrow cultivation system can decrease the shading of wheat. A ridge of 10 cm height for cotton in the intercropping systems, which has the same effect as decreasing plant height of wheat, will increase the light interception of cotton during intercropping period (Zhang, 2007). Wasaya et al. (2013) have also reported such opinion stating that wheat-fenugreek intercropping are most effective for sustainable production and a higher net return. The system of planting wheat + 2 rows of cotton on 150 cm apart ridges (P2) or 6:2 system, has shown it's worth to be adopted and used successfully for relay cropping of cotton in standing wheat crop for having additional economic benefits in this new Bt cotton-wheat cropping system.

CONCLUSIONS

Relay cropping of Bt-cotton provides an opportunity not only to plant Bt-cotton timely (first fortnight of March) by reducing turnaround time to 30-45 days (from seasonal crop sown in May) but also to get the optimum yield of wheat. Furthermore, there is no cost involved for land preparation for planting Bt cotton that helped to save Rs. 8000 per hectare. It has been observed that P_2 (wheat + 2 rows of cotton on 150 cm apart ridges) recorded highest BCR value (1.92) with maximum per hectare income followed by P_1 (wheat+1 row of cotton on 150 cm apart ridges) in comparison with the farmer practice as Bt cotton alone (P_6) and conventional cropping system of wheat after cotton (P_5). These two (P_1 and P_2,) systems, preferably P_2 (6:2), can successfully be used for relay cropping of cotton in standing wheat crop for better economic benefits ensuring food security in this new, Bt-cotton-wheat, cropping system.

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