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Economics of Bt cotton based cropping systems in Vidarbha

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Abstract
The field research exploration was successfully conducted at Research Farm of Agriculture Research Station, Yavatmal under Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola in Vidarbha region during consecutive seasons of *Kharif–Rabi-Summer* 2020-21 to 2022-2023. The Bt cotton based cropping system was investigated under optimal resource utilization with six different cropping systems for profitability in Vidarbha region. The mid late duration *kharif* cotton (PDKV JKAL-116) −summer groundnut (TAG-24) cropping sequence witnessed significantly the highest cotton equivalent yield (4301 kg ha^{-1}) with highest GMR (Rs. 248206 ha^{-1}), NMR (Rs. 167117 ha^{-1}) and B:C ratio of 3.06, during field investigation. However, early duration *kharif* cotton (Ajit-5)−chickpea cropping sequence (C_3) registered the highest system profitability of Rs. 476 kg/day/ha, which was closely followed by cropping system C_6 i.e. mid late duration *kharif* cotton− summer groundnut sequence (Rs. 474 kg/day/ha).

Keywords: Cropping system, cotton equivalent yield, economics, production efficiency, system profitability

Introduction
Cotton (*Gossypium* spp.) crop is also popularly known as 'white gold' which plays an important role in textile and other allied industries. The cotton production in India during 2023-24 was 316.57 lakh bales from 123.42 lakh hectares with a productivity of 441 kg lint/ha. During the year 2023-24, Gujarat (89.44 lakh bales), Maharashtra (75.75 lakh bales), Telangana (47.99 lakh bales), Rajasthan (28.10 lakh bales) and Karnataka (19.29 lakh bales) were the major cotton growing states in India. Whereas, Maharashtra ranks first in cotton area 42.22 lakh ha followed by Gujrat, Telangana, Rajasthan and others. (Anonymous, 2024) [2].

Cotton the king of fiber, is one of the momentous and an important cash crop exercising profound influence on economics and social affairs of the world. Cotton seed contains 15 to 20 percent oil and is used in vegetable purpose and soap industries.

Crop diversity improve crop productivity and profitability, conservation of resources and provide a kind of biological insurance against risks and aberrant rainfall behavior in rainfed condition like vidarbha where 80% farming is rainfed. (Dutta and Bandyopadhyay, 2006) [4]. The diversification is desirable in rotation with other cereals and pulses like wheat (*Triticum aestivum* L.), Linseed (*Linum usitatissimum*), pigeonpea (*Cajanus cajan*), chickpea (*Cicer arietinum*), groundnut (*Arachis hypogaea* L.), green gram (*Vigna radiata*) in sustainable multiple agriculture systems with more efficient use of resources (light, water, nutrients) or reduced pest damage. The cotton crop allows crop rotation or crop sequence with high-value crops like legumes and oilseed crops, which might be a way for farmers to optimize their use of resources.

Indian agriculture is struggling with nutrient imbalance, soil degradation, lowering of water table, salinity, resurgence of pests and diseases, environmental pollution and resulting in declining farm profit. The crop sequences with multiple crops are practiced in rainfed areas which reduce the risk factor of crop failures due to drought. This will be helpful for vidarbha region which has more area under *rainfed* crops. Crop diversification through cropping sequence recognized as an effective strategy for achieving the objectives of food security, income growth, nutrition security, poverty alleviation and employment generation, judicious

use of land and water resources, sustainable agricultural development and environmental improvement.

As cotton allows crop rotation or crop sequence with high-value crops like legumes and oilseed crops Bt based cotton crop sequence might be economical in Vidarbha region. The selection of appropriate cultivar in any sequence is the key factor (Nichols *et al.*, 2004) [7]. Therefore, short duration cotton genotypes are economical regarding cost of production because early maturing cultivars evade from biotic and abiotic risks, also not only minimize the use of pesticides, but also the expenses incur on the other inputs like irrigation water and fertilizers will be condensed down. (Rehana *et al.*, 2001) [9]. The rainfed farming in vidarbha with unequal, erratic distribution make farming defenseless for sole cropping. Hence, an effort has been made to scrutinize dominated cotton as base crop with mid late and early duration *Bt* cultivars in cropping sequence with *rabi* wheat, linseed, chickpea and summer groundnut and green gram crops, which may promote diversification of crops under optimal resource utilization with high returns.

Materials and Methods

The research investigation was conducted during consecutive seasons of *Kharif–Rabi-Summer* 2020-2021 to 2022-2023 at Agriculture Research Station, Waghapur Road, Yavatmal under Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS). The total rainfall received during the seasons of 2020, 2021 and 2022 at research site, was 1092.5 mm, 1229.8 mm and 1378.0 mm in 50, 57 and 60 rainy days, respectively as against normal annual precipitation of 926.3 mm in 62 rainy days. The research site was clayey in texture and moderately alkaline in reaction, medium in organic carbon (0.64%), low available nitrogen (237.5 kg ha^{-1}) and phosphorus (23.5 kg ha^{-1}) while high in available potassium 643.9 kg ha^{-1}. The treatments comprised of six cropping sequences which includes C_1: Sole Bt Cotton (Mid-late duration), C_2: Bt-cotton (Early duration)−Wheat, C_3: Bt-cotton (Early duration)−Chickpea, C_4- Bt-cotton (Early duration)−Linseed, C_5: Bt-cotton (Early duration)− summer green gram, C_6: Bt-cotton (Mid late duration)− summer Groundnut and C_7: Bt-cotton (Early duration) + Pigeonpea (6:2 Farmer Practice, Rainfed) were laid out in Randomized Block Design replicated thrice. The suitable cultivars were chosen for experiment which were early duration cotton ACH-5 BGII (Ajeet-5 BGII), mid late duration cotton (PDKV JKAL-116), pigeonpea (PKV Tara), wheat (PDKV Sardar), linseed (NL-260), chickpea (PDKV Kanchan), summer groundnut (TAG-24) and summer green gram (Pusa vaishakhi). The recommended package of practices *viz.*, land preparation, fertilizer, weeds control and plant protection measures were implemented to make the crop free from insects and diseases throughout the year. The data were recorded on five randomly selected plants of each plot of each replication related to growth, yield and after harvest soil studies.

Results

Seed cotton and cotton equivalent yield

There was significant influence of cropping sequences in terms of seed cotton, lint yield and groundnut equivalent yield observed in the pooled data. The pooled data presented in Table 1 revealed that, sole mid late duration Bt cotton C_6 and C_1 system noted significantly highest seed cotton yield of 2067 and 1990 kg ha^{-1}, respectively above early duration Bt cotton cultivars. In sequence crops, *rabi* and summer sequence registered more or less similar yield response in wheat, chickpea, linseed and summer groundnut and green gram yield when sown as sole crop and reflected in the pooled data.

Cotton equivalent yield was significantly influenced due to different cropping sequences. Mid late duration Bt cotton - summer groundnut cropping sequence (C_6) registered significant supremacy to cotton equivalent yield in individual as well as in pooled years (3796, 4445, 4663 and 4301 kg ha^{-1}, respectively) over rest of all cropping sequences. This percent increment in crop equivalent yield in pooled data was to the tune of 223.66% over sole mid late duration Bt cotton crop. Cropping sequence C_6 (mid late duration Bt cotton - summer groundnut) was closely followed by early duration Bt cotton− chickpea cropping sequence (C_3), which recorded cotton equivalent yield of 3387 kg ha^{-1} and extent of increment was 176.13% over sole mid late duration Bt cotton. Farmers practice i.e. early duration Bt cotton + pigeonpea intercropping (6:2) and sole mid late duration Bt cotton recorded the lowest cotton equivalent yield 1856 and 1990 kg ha^{-1}, respectively.

System productivity, profitability and relative productive efficiency

Crop production efficiency of cropping system, based on the actual crop duration noted numerically higher under early duration Bt cotton− chickpea (C_3) cropping sequence i.e. 1263 kg ha^{-1} day^{-1}, which was intimately followed by mid late duration Bt cotton - summer groundnut (C_6) crop sequence (1212 kg ha^{-1} day^{-1}). The relative productive efficiency of system was noticed higher in mid late duration Bt cotton - summer groundnut (116.15%) cop sequence and it was followed by Bt cotton−chickpea cropping sequence (70.21%) than that of sole mid late duration Bt cotton cropping.

The Bt cotton−chickpea (C_3) cropping sequence witnessed the highest system profitability of Rs. 476 day^{-1} ha^{-1} over rest of cropping sequences and closely followed by mid late duration Bt cotton - summer groundnut crop sequence i.e. Rs. 474 day^{-1} ha^{-1} . The comparatively more cropping period i.e. 355 days were required for completion of mid late duration Bt cotton - summer groundnut crop sequence, whereas shortest days (228 days) were registered under early duration Bt cotton- summer green gram cropping system (Table 3).

Economics

The pooled data demonstrated in Table 3 revealed that, cropping sequence C_6 i.e. mid late duration Bt cotton - summer groundnut noted significantly highest gross and net monitory returns of Rs. 248206 ha^{-1} and Rs. 167117 ha^{-1}, respectively over other cropping sequences under investigation. Whereas, mid late duration Bt cotton - summer groundnut cropping sequence (C_6) was closely followed by early duration Bt cotton− chickpea cropping sequence (C_3), which recorded gross and net monitory returns of Rs. 195505 ha^{-1} and Rs. 125461 ha^{-1}, respectively. Significantly the lowest gross and net monitory returns were observed in early duration Bt cotton + pigeonpea intercropping (6:2) and sole mid late duration Bt cotton sequences. Besides this, mid late duration *Bt* cotton−summer groundnut cropping sequence (C_6) reported highest benefit to cost ratio of 3.06 over early duration Bt cotton−chickpea crop sequence (2.79).

Discussion

The comparatively longer growing period availability, good crop growth and establishment leads to significantly highest seed cotton yield response in cropping sequence C_6 and C_1 (sole mid late duration Bt cotton). The late sowing of cotton decreases the yield contributing traits and ultimately the seed cotton yield (Iqbal *et al.*, 2012) [6]. The cotton equivalent yield under mid late duration Bt cotton- summer groundnut cropping sequence was noted significantly highest, as mid late Bt cotton attributed to better productivity and higher remuneration in summer groundnut generating an additional increment in cotton yield which ultimately helped to reach level of significance over rest of the treatments. this results are in confirmatory with those reported by Walia *et al.*, (2010) [11] and Patel *et al*., (2019) [8]. Desai *et al.* (2022) [4] reported that, dynamicity of cropping system should not based on single year but also on subsequent crop sequence effects. Therefore, more productivity and market rates of the sequence crops with low input cost also helped in witnessing higher cotton equivalent yield and economics returns which ultimately affects system productivity and profitability, Singh and Ahlawat (2012) [10].

The cropping sequence mid late duration Bt cotton- summer groundnut followed by early duration Bt cotton− chickpea was economically more viable than sole Bt cotton and other cropping systems. Besides this, considering the duration of crop sequence, early duration Bt cotton− chickpea system was slightly more remunerative than mid late duration Bt cotton- summer groundnut sequence. These findings are in confirmatory with Gangawar *et al.* (2012) [5] and Turkhede *et al*., (2017) [1].

Table 1: Seed cotton, sequence crop and cotton equivalent yield influenced by treatments of the system

Treatments	Seed cotton yield (kg/ha)				Sequence crop yield (kg/ha)								Cotton equivalent yield (kg/ha)			
					Rabi season				Summer season							
	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled
C1	1883	1997	2089	1990	--	--	--	--	--	--	--	--	1883	1997	2089	1990
C2	1474	1669	1609	1584	2817	3146	3136	3033	--	--	--	--	2464	2776	2705	2648
C3	1446	1713	1767	1642	1895	1926	2073	1965	--	--	--	--	3102	3472	3586	3387
C4	1475	1698	1644	1606	996	1003	942	980	--	--	--	--	2316	2583	2488	2462
C5	1445	1702	1794	1647	--	--	--	--	676	653	728	686	2328	2532	2723	2528
C6	1948	2061	2192	2067	--	--	--	--	1930	2459	2568	2319	3796	4445	4663	4301
C7	1610	1963	1996	1856	--	--	--	--	--	--	--	--	1610	1963	1996	1856
Mean	1611	1829	1870	1770	815	868	879	854	372	445	471	429	2500	2824	2893	2739
SE (m)±	60	48	75	40	--	--	--	--	--	--	--	--	62	55	100	51
CD at 5%	185	147	231	124	--	--	--	--	--	--	--	--	191	168	309	159

C1: Sole Bt Cotton (Mid-late duration); C2- Bt-cotton (Early duration)- Wheat; C3- Bt-cotton (Early duration)- Chickpea; C4- Bt-cotton (Early duration)- Linseed; C5- Bt-cotton (Early duration)- summer green gram; C6- Bt-cotton (Mid late duration)- summer Groundnut; C7- Bt-cotton (Early duration) + Pigeonpea (6:2 FP, Rainfed)

Table 2: Relative production efficiency, production efficiency, system productivity and cropping period as influenced by treatments of the system

Treatments	Production Efficiency (kg/ha/day)				System Profitability (Rs/day/ha)				System Profitability (Rs/day/ha)				Cropping period (days)			
	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled
C1	753	815	856	808	236	275	319	277	250	245	244	246	--	--	--	--
C2	963	1089	1036	1029	277	356	355	329	256	255	261	257	30.86	39.00	29.47	33.10
C3	1170	1305	1314	1263	414	484	529	476	265	266	273	268	64.73	73.87	71.65	70.21
C4	880	975	925	927	259	322	317	299	263	265	269	266	22.98	29.31	19.08	23.73
C5	1030	1120	1179	1110	330	392	459	394	226	226	231	228	23.64	26.77	30.32	27.03
C6	1060	1259	1317	1212	368	491	561	474	358	353	354	355	101.57	122.55	123.18	116.15
C7	826	1002	1008	945	203	311	339	284	195	196	198	196	-14.51	-1.71	-4.45	-6.71
Mean	955	1081	1091	1042	298	376	411	362	259	258	261	259	33	41	38	38
S.E(m)±	--	--	--	--					--	--	--	--	--	--	--	--
CD at 5%	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

C1: Sole Bt Cotton (Mid-late duration); C2- Bt-cotton (Early duration)- Wheat; C3- Bt-cotton (Early duration)- Chickpea; C4- Bt-cotton (Early duration)- Linseed; C5- Bt-cotton (Early duration)- summer green gram; C6- Bt-cotton (Mid late duration)- summer Groundnut; C7- Bt-cotton (Early duration) + Pigeonpea (6:2 FP, Rainfed)

Table 3: Economics of the system as influenced by treatments of the system

Treatments	Gross monitory return (Rs/ha)				Net monitory return (Rs/ha)				Cost of cultivation (Rs/ha)				B: C ratio			
	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled	2020-21	2021-22	2022-23	Pooled
C1	103752	114358	127026	114851	59060	67431	77746	67885	44692	46927	49280	46966	2.32	2.44	2.58	2.45
C2	135767	158955	164462	152859	70808	90749	92622	84523	64959	68207	71840	68335	2.09	2.33	2.29	2.24
C3	176308	198830	218047	195505	109668	128858	144527	125461	66640	69972	73520	70044	2.65	2.84	2.97	2.79
C4	127591	147877	151260	142176	68103	85414	85256	79524	59488	62462	66004	62651	2.14	2.37	2.29	2.27
C5	128279	144971	165541	145875	74662	88673	106026	89398	53617	56298	59515	56477	2.39	2.58	2.78	2.58
C6	209133	254506	283495	248206	131646	173472	198749	167117	77487	81033	84746	81089	2.70	3.14	3.35	3.06
C7	88697	112400	121367	107146	39544	60987	67160	55555	49153	51413	54207	51591	1.80	2.19	2.24	2.08
Mean	138504	161700	175885	158088	79070	99369	110298	95638	59434	62330	65587	62450	2.30	2.55	2.64	2.49
S.E(m)±	3422	3130	6104	2976	3422	3130	6104	2976	--	--	--	--	--	--	--	--
CD at 5%	10544	9643	18808	9170	10544	9643	18808	9170	--	--	--	--	--	--	--	--

C1: Sole Bt Cotton (Mid-late duration); C2- Bt-cotton (Early duration)- Wheat; C3- Bt-cotton (Early duration)- Chickpea; C4- Bt-cotton (Early duration)- Linseed; C5- Bt-cotton (Early duration)- summer green gram; C6- Bt-cotton (Mid late duration)- summer Groundnut; C7- Bt-cotton (Early duration) + Pigeonpea (6:2 FP, Rainfed)

		Cotton	Pigeonpea	Wheat	Chickpea	Linseed	S. green gram	S. Gr. nut
Selling price per kg (Rs)	2020-21	55.1	63.04	19.37	48.15	46.5	71.96	52.75
	2021-22	57.26	63.0	20.15	52.03	50.5	72.75	55.50
	2022-23	60.80	66.0	21.25	53.35	54.50	77.55	58.50

Conclusion

The cropping systems approach provides opportunities to increase economic returns, as sole cotton cropping becoming nutrient exhaustive with static cotton crop production in vidarbha region. Therefore, mid-late duration *Bt* cotton - summer groundnut cropping system noticed significantly the highest cotton equivalent yield, gross monitory returns, net monitory returns and benefit to cost ratio was observed under the investigation.

However, early duration *kharif* cotton- chickpea cropping system recorded higher production efficiency and system profitability owing to its less cropping period cover within a year. Therefore, mid-late duration *Bt* cotton - summer groundnut or early duration *Bt* cotton - chickpea cropping sequence are found to be most suitable and efficient for vidarbha region for sustaining productivity.

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