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Effects of Cotton–Peanut Intercropping Patterns on Cotton Yield Formation and Economic Benefits

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Intercropping has been widely adopted by farmers because it often enhances crop productivity and economic returns. However, to increase the comprehensive production benefits of agricultural cultivation and increase the economic benefits of cotton in Northwest Shandong Province, a set of green, ecological, and efficient intercropping mode suitable for Northwest Shandong Province was preliminarily formed. A 2-year intercropping experiment was conducted in Xiajin and Dongping counties in Shandong Province, with six alternative intercropping patterns proposed. After analyzing the experimental data, it was determined that the traditional cotton–peanut intercropping method is not mechanized and that a new intercropping mode has been proposed: four rows of cotton and six rows of peanut. We selected the appropriate intercropping mode for Xiajin and Dongping counties. The production efficiency of 4:4 cotton intercropping in Peanut Ridge was the best in Dongping and Xiajin counties, which was 28–123% higher than that of monoculture. This planting pattern is suitable for demonstration and promotion in the two counties, as well as in the traditional cotton area of the old Yellow River in Northwest Shandong.

Keywords: cotton, peanut, intercropping, economic benefit, yield

INTRODUCTION

Cotton is the main fiber crop, and peanut is a popular oil crop in China (Chi et al., 2019; Wang et al., 2021). The incompatibility with cotton and grain, oil, vegetables, melon, and fruit has become one of the major impediments to the development of cotton production (Abd El-Zaher Sh et al., 2009; Ahmed et al., 2015). The development of a multi-maturity, three-dimensional intercropping mode is essential to improving planting efficiency, resolving cropland conflict, and stabilizing cotton production. Peanuts have a good nitrogen-fixing ability, and they can improve the utilization rate of land and resources in time and space through the rational allocation of crop population (Chen et al., 2016). Peanut root properties and soil distribution are complementary to cotton, which may increase soil fertility and allow for a combination of land and nutrition uses (Singh and Ahlawat, 2011; Singh et al., 2015). Numerous studies have shown that intercropping of Gramineae and legumes improve the ecological environment of farms through interspecific competition and spatial complementarity (Latati et al., 2014; Singh et al., 2017).

Planting two or more crop species in the same field and at the same time is known as intercropping (Li et al., 2001, 2003; Stomph et al., 2020). Intercropping has become popular in Asia and Africa because it allows farmers to make the most of available resources (Jordan et al., 2017; Chi et al., 2019). Intercropping patterns that are commonly used include legume/cereal, cotton/cereal, and legume/cotton. These intercropping arrangements allow not only the interception and utilization of sunlight energy and the absorption and utilization rate of water and fertilizer, but they also increase the biodiversity of farmland, effectively suppress weeds, and reduce the occurrence of diseases and insect pests, thus improving the system productivity and promoting the sustainable development of agriculture (Zhang et al., 2010; Gitari et al., 2017; Jordan et al., 2017). Cotton and peanuts are commonly grown in China, and cotton–peanut intercropping is widely utilized to harvest both crops simultaneously (Jordan et al., 2017; Zhao Y. et al., 2019; Salama et al., 2022). In addition, crop diversity in cotton–peanut intercropping systems increased soil environment and field stability (Zhang et al., 2016; Chen et al., 2018) found that in the maize/peanut intercropping system, intercropping enhanced the utilization capacity of maize to strong light, increased the net photosynthetic rate of functional leaves at the late growth stage of maize, and promoted the distribution of photosynthetic substances to grains, and produced in an obvious yield advantage (Singh and Ahlawat, 2013; Qian et al., 2018). At present, the commonly used intercropping patterns include two rows of cotton and peanut (2:2), two rows of cotton and three rows of peanut (2:3), two rows of cotton and four rows of peanut (2:4), and four rows of cotton and two rows of peanut (4:2). Farmers in the Yellow River Basin often harvest two crops in a year, believing it will increase their economic income. Cotton–peanut intercropping can meet these needs (Afrin et al., 2017; Gao et al., 2020; Gowton et al., 2021). However, because the traditional cotton–peanut intercropping method is not mechanized, a new intercropping mode has been proposed: four rows of cotton and six rows of peanut (Xu et al., 2013; Liang et al., 2020; Tang et al., 2020).

In Northwest Shandong Province, Xiajin and Dongping counties are both located on the alluvial plain of the historic Yellow River Channel. Monoculture cotton has been the main cultivation method in Xiajin and Dongping counties for many years. In recent years, the monoculture has led to low land yield, low cotton yield, and sparse comparative benefits. Monoculture cotton has resulted in the degradation of soil's physical and chemical structure, resulting in soil hardening, a decrease in soil fertility, and a decrease in ecological benefit due to its single planting structure. Furthermore, the market price of cotton has been low in recent years; the international trading environment for cotton has been severely hampered, and the cost of cotton planting has increased (Singh et al., 2015; Liu et al., 2019; Maitra et al., 2021). Cotton planting benefits are dwindling in both counties. Cotton planting regions are also gradually concentrated on saline-alkaline and sandy dry land. Innovation and development in the cotton-growing sector must find better planting models (Li et al., 2021; Li W. et al., 2022).

We have developed a series of green. Such an approach is needed to promote ecologically more diverse cropping systems that may be better suited to serve the multiple functions of northwest Shandong by conducting innovative experiments on cotton production and cultivation techniques to study the impact of cotton and peanut planting patterns on land resource use and changes to be further determined in soil structure and properties, crop yield, and field income. Our ultimate goal is to determine the feasibility and advantages of cotton/peanut intercropping, as well as the underlying mechanisms.

MATERIALS AND METHODS

Field Experimental Site and Cultivar

In 2018 and 2019, two field trials were conducted in Dongping County (116.48°E, 35.94°N), Tai'an City, Shandong Province of China, and Xiajin County (116.00°E, 36.95°N), and Dezhou City, Shandong Province of China. Luhua 8 was chosen as the peanut cultivar, and Lu6269 was chosen as the cotton cultivar in this experiment.

Experimental Design and Field Management

In 2018 and 2019, seven treatments were set up; monoculture of cotton (M), two rows of cotton and four rows of peanut intercropping (F2:4), four rows of cotton and four rows of peanut intercropping (F4:4), four rows of cotton and six rows of peanut intercropping (F4:6), two rows of cotton and four rows of peanut intercropping (R2:4), four rows of cotton and four rows of peanut intercropping (R4:4), and four rows of cotton and six rows of peanut intercropping (R4:6).

Monoculture cotton was planted on the flat land at a planting density of 67,500 plants ha^{-1}. Each plot measured 60.8 m^2 (6.08 m × 10 m) with a row spacing of 76 cm.

Cotton and peanut intercropping, cotton planting density of 67,500 plants ha^{-1}, and a row spacing of 76 cm. Peanut planting methods were classified as ridge planting and flat planting, with a row spacing of 30 cm, respectively, and a planting density of 300,000 plants ha^{-1}. The distance between cotton and peanut was 70 cm.

For 2 years, between mid- and late-February, chicken manure 20 thm^{-2} nitrogen, phosphorus, and potassium compound fertilizer 380 $kghm^{-2}$ was used as the base fertilizer on cultivated land. After sowing, the second true cotton leaf was coated, and the seedlings were planted. Peanut seeds were planted at the time of 2–3 pairs of true leaves.

Yield and Yield Components

Yield samples were collected 1 day before harvest. After drying for 14 days, the yield and yield composition of peanut and cotton were determined, respectively. At harvest, peanut pods from 10 randomly sampled plants were weighed after sun-drying for 14 days. Peanut pod yield and 100-pods weight were collected (Chi et al., 2019). For cotton, all plants were collected in the sampling area to quantify cotton seed, cotton yield, boll density, and weight. After bolling, the seed cotton in the plot was gradually harvested. After drying, weight was used to calculate the yield of seed cotton in plots.

Benefit-Cost Measurement

Material inputs such as seeds, fertilizers, pesticides, and irrigation systems, as well as labor costs such as fertilization, irrigation, weeding, and harvesting, were recorded at each experimental station. Input costs were calculated according to the local material and labor daily prices in Shandong Province, while the production costs of peanut pods and seed cotton were calculated according to the average local market prices in Shandong Province in 2018 and 2019.

Data Collection

Data were collected for the cotton growth and development process, cotton yield and yield components, cotton plant biomass accumulation, cotton production cost, and economic benefits.

Statistical Analysis

Data were analyzed following analysis of variance 35, and means of crop management treatments were compared based on the least significant difference test (LSD) at the 0.05 probability.

RESULTS

Growth and Development Process

Different intercropping strategies for Xiajin cotton in 2018 had no effect on the sowing to squaring process; nevertheless, intercropping advanced flowering and boll opening, with F2:4 and R2:4 flowering 2 days earlier and bolls opening 4 days earlier than in monoculture cotton. The flowering time of other intercropping configurations was 1 day earlier, and the boll-setting time was 2 days earlier. In 2018, the process of cotton growth and development was delayed in Xiajin County, with seeding being 1–2 days slower than monoculture cotton, squaring being 2 days slower, flowering being 8 days slower, and boll opening being 3 days slower, while in 2019, only boll opening monoculture was 3 days slower than intercropping in Dongping County. Intercropping delayed the growth and development of cotton in Xiajin County. Intercropping seedlings were 1–2 days slower than monoculture cotton; seeding occurred 2 days later, flowering occurred 5 days later, and boll opening occurred 3 days later (**Table 1**).

Yield and Yield Components

The yield of cotton seed during 2018 in Dongping is shown in **Table 2**. This stable shows that the yield of cotton seed was high at M (258.97 kg ha^{-1}). Similarly, the estimated yield of cotton seed under F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6 shows a decline of 45.7, 27.8, 40.5, 3.0, 47.7, and 32.8%, respectively, from the yield of cotton seed at M. The results also show that the lint cotton yield was observed to be high at M (106.38 kg ha^{-1}) during 2018 in Dongping, while the lint cotton yield showed a decline of 44.2, 27.3, 39.6, 3.0, 47.0, and 31.0% under F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6. The study also observed that the cottonseed yield during 2019 in Dongping was high at M (253.88 kg ha^{-1}), but at F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6, the cottonseed yield dropped by 46.2, 29.3, 41.7, 2.3, 48.9, and 34.3%. In 2019, in Dongping, the highest lint cotton yield was 102.36 kg ha^{-1} at M, but it showed a reduction of 43.8, 28.2, 39.8, 2.8, 46.6, and 31.1% lint cotton yield under F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6 flat.

The estimated result of Xiajin during 2018 shows that the seed cotton yield was low at M (307.27 kg ha^{-1}), but it showed a rise of 26.1, 30.0, 0.24, 5.9, 13.6, and 5.7% in cottonseed yield under F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6 flat. Similarly, the lint cotton yield was observed to be low at M (132.72 kg ha^{-1}), but it showed growth of 28.0, 30.6, 0.25, 4.9, 14.0, and 6.6% in lint cotton yield under F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6 flat. The study also observed that the cottonseed yield during 2019 in Xiajin was low at M (291.93 kg ha^{-1}), but it showed a growth of 26.3, 34.1, 2.4, 9.5, 15, and 5.7% in seed cotton yield under F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6 flat. Similarly, the lint cotton yield was observed to be low at M (127.5 kg ha^{-1}), but it was increased by 26.0, 33.3, 0.28, 6.0, 15.1, and 5.4% under F2:4, F4:4, F4:6, R2:4, R4:4, and R4:6 flat.

In 2018, in Dongping, the lint percentage of F2:4 was the highest, which was 2.7% higher than M. The boll number of F2:4 was the highest, which was 9.8% higher than M. Dongping in 2019; the lint percentage of F2:4 was the highest, which was 4.8% higher than M. The boll number of F2:4 was the highest, which was 5.2% higher than M. Xiajin in 2018; the lint percentage of F2:4 was the highest, which was 1.0% higher than M. The boll number of F2:4 was the highest, which was 19.7% higher than M. Xiajin in 2019; the lint percentage of F2:4 was the highest, which was 3.6% higher than M. The boll number of F2:4 was the highest, which was 19.5% higher than M (**Table 2**).

Cotton Biomass Accumulation

Between 2018 and 2019, in Dongping and Xiajin Counties, the ROB accumulation of monoculture cotton was the highest at squaring, first flowering, and boll opening and the lowest at full bolling. At initial and full flowering, ROB accumulation were 69.4–67.9%, and 35.4–38.3% that were lower than that of monoculture cotton, respectively. At the boll opening stage, F4:4 had the lowest ROB accumulation, which was 52.2–5.2% lower than that of monoculture cotton. F4:6 had the lowest ROB accumulation at squaring, which was 59.8–63.8% lower than monoculture cotton. R2:4, The ROB accumulation of R2:4 was the highest in all cropping-—178.0–202.1% higher than that in monoculture cotton. At full flowering, R4:6 had the highest ROB accumulation, which was 1.0–6.8% more than monoculture cotton (**Tables 3**, **4**).

In 2018, the largest VOB accumulation occurred in R2:4 monoculture, R4:4, F2:4, and R2:4 treatments at squaring, first and full flowering, full bolling, and boll opening were in R2:4. The minimum accumulative quantities were F4:4, F2:4, F2:4, monoculture, and F4:4. In Dongping County, the maximum accumulation of VOB was 17.2, 57.3, 43.6, 77.1, and 102.2% greater than the minimum accumulation, while in Xiajin County, the maximum accumulation was 19.5, 57.7, 40.9, 77.1, and 106.1% greater than the minimum accumulation (**Tables 3**, **4**).

TABLE 1 | Cotton growth and development process (days after sowing) in Dongping and Xiajin counties from 2018 to 2019.

Year	Location	Trt	Sowing	Seeding	Squaring	Flowering	Boll opening
2018	Dongping	M	4/28	5	51	72	117
		F2:4	4/28	5	51	70	113
		F4:4	4/28	5	51	71	115
		F4:6	4/28	5	51	71	115
		R2:4	4/28	5	51	70	113
		R4:4	4/28	5	51	71	115
		R4:6	4/28	5	51	71	115
	Xiajin	M	4/23	12	46	68	125
		F2:4	4/23	13	48	76	128
		F4:4	4/23	13	48	76	128
		F4:6	4/23	14	48	76	128
		R2:4	4/23	13	48	76	128
		R4:4	4/23	13	48	76	128
		R4:6	4/23	14	48	76	128
		LSD	**1**	**1**	**1**	**1**	**1**
2019	Dongping	M	4/28	7	55	74	120
		F2:4	4/28	7	55	74	117
		F4:4	4/28	7	55	74	117
		F4:6	4/28	7	55	74	117
		R2:4	4/28	7	55	74	117
		R4:4	4/28	7	55	74	117
		R4:6	4/28	7	55	74	117
	Xiajin	M	4/23	9	44	68	123
		F2:4	4/23	11	46	73	126
		F4:4	4/23	11	46	73	126
		F4:6	4/23	12	46	73	126
		R2:4	4/23	11	46	73	126
		R4:4	4/23	11	46	73	126
		R4:6	4/23	11	46	73	126
		LSD	**1**	**1**	**1**	**1**	**1**

Values followed by the same letters indicate non-significance difference among treatments within years at $P < 0.05$ (LSD test).

In Dongping County, the maximum accumulation of VOB from various treatments was in the R2:4, monoculture, R4:4, R2:4, and R2:4, respectively, in 2019. The minimum accumulation was F4:6, F2:4, R2:4, monoculture, and F4:4, respectively. The maximum accumulation of VOB in Dongping County was 13.3, 155.0, 43.0, 75.0, and 107.8% higher than the minimum accumulation of VOB. In 2019, the maximum VOB accumulation in different treatments of Xiajin County was in the treatments of R2:4, monoculture, R4:4, R2:4, and F4:4, respectively. The minimum accumulation was R4:4, F2:4, R2:4, monoculture, and F4:4. At various growth stages in Xiajin County, the maximum accumulation of VOB was 26.4, 147.7, 34.7, 64.5, and 111.1% greater than the minimum accumulation (**Table 4**).

Donping and Xiajin counties had the least organ biomass accumulation at squaring from 2018 and 2019 and the difference between treatments were modest. Monoculture had the largest accumulation of organ biomass at first flowering, while R2:4 and F2:4 had the lowest. The organ biomass accumulation of R4:6 was the most at full flowering, and that of R2:4 was the least. The organ biomass accumulation of R2:4 and F2:4 was greater at full bolling, whereas the organ biomass accumulation of monoculture was the least. At boll opening, monoculture had the largest biomass accumulation of organs, while F4:4 and R4:4 had the lowest (**Figure 1**).

Cost and Benefit

The net income of F4:4 and R4:4 was the highest in Dongping and Xiajin counties in 2018, while the net income of monoculture was the lowest. R4:4 and F4:4 had a net income of 123.3% higher than that of monoculture (**Table 5**). In 2019, Dongping and Xiajin Counties had the highest net income of R4:4 and the lowest net income from monoculture. Dongping County and Xiajin County increased by 127.8 and 125.6%, respectively (**Table 5**). Under the same treatments, the net incomes of Dongping and Xiajin counties were comparable. In Dongping County, the net income of each treatment is often lower than it is in Xiajin County. This is because Dongping County's lint and seed cotton yields were

TABLE 2 | From 2018 to 2019, cotton yield and yield components (Dongping and Xiajin).

Year	Location	Trt	Boll number (bolls plant $^{-1}$)	Boll weight (g boll^{-1})	Seed cotton yield (kg ha^{-1})	Lint cotton yield (kg ha^{-1})	Lint percentage (%)
2018	Dongping	M	13.3	4.96	258.97	106.38	41
		F2:4	14.6	4.78	140.58	59.35	42.1
		F4:4	14.2	4.57	187.02	77.36	41.3
		F4:6	13.7	4.54	154.02	64.22	41.6
		R2:4	12.5	4.75	251.22	103.14	39.8
		R4:4	13.9	4.52	135.36	56.36	39.2
		R4:6	13.2	4.21	173.94	73.43	39.3
	Xiajin	M	15.7	4.33	307.27	132.72	43.2
		F2:4	18.8	4.52	387.42	169.88	43.6
		F4:4	18.5	4.7	399.36	173.34	43.4
		F4:6	15.4	4.39	308.01	133.05	43.2
		R2:4	16.3	4.39	325.51	139.22	42.7
		R4:4	16.5	4.62	348.98	151.26	43.3
		R4:6	15.8	4.52	324.87	141.43	43.5
		LSD	**2.2**	**0.81**	**19.30**	**15.25**	**1.7**
2019	Dongping	M	13.5	4.88	253.88	102.36	39.4
		F2:4	14.2	4.69	136.49	57.55	41.3
		F4:4	13.8	4.45	179.55	73.49	40.5
		F4:6	13.3	4.36	147.97	61.65	39.6
		R2:4	11.9	4.54	246.26	99.52	37.8
		R4:4	13.2	4.32	129.61	54.66	37.2
		R4:6	12.9	4.13	166.92	70.52	37.7
	Xiajin	M	15.4	4.12	291.93	127.5	41.3
		F2:4	18.4	4.35	368.85	160.64	42.8
		F4:4	17.8	4.62	391.46	169.95	42.1
		F4:6	14.6	4.26	298.89	127.86	41.5
		R2:4	15.6	4.33	319.58	135.1	41.1
		R4:4	16.2	4.54	335.67	146.73	42.5
		R4:6	15.2	4.38	308.65	134.36	42.7
		LSD	**2.0**	**0.76**	**18.52**	**13.91**	**1.4**

Values followed by the same letters indicate non-significance difference among treatments within years at $P < 0.05$ (LSD test).

lower than those in Xiajin County, resulting in lower sales and thus poorer net income in Xiajin County. Cotton and peanut intercropping will raise production costs. Seed, planting, and artificial inputs are the key cost increases. Intertillage, fertilizer, and pesticide input remain unchanged. Its net income was higher than the final net income, demonstrating that these inputs were worthwhile. R4:4 offers the best production benefits in both places, based on net income in 2018 and 2019 (**Table 5**).

DISCUSSION

In Dongping and Xiajin counties, the impact of cotton monoculture and various cotton–peanut intercropping patterns on cotton growth and development, yield components, biomass accumulation of multiple organs, costs, and benefits of cotton production were investigated. The F4:4 model had the highest yield in Xiajin County, with a 30 and 34.1% increase in yield over 2 years compared with monoculture seed cotton. Among six intercropping patterns, the 2-year yield of R2:4 was the highest in Dongping County, which was 27.8 and 3.0% lower than that of monoculture cotton. The net profit of cotton and peanut intercropping is 127.8% higher than that of cotton monoculture. This research offers a new perspective on cotton growing in Shandong Province. The cotton and peanut intercropping option increases field utilization efficiency. Even though it only increases a modest amount of investment, it has a significant impact on economic benefit (Yang et al., 2017; Zhao W. et al., 2019; Zhi et al., 2019). It is a critical innovation that will help boost the economic benefits of cotton production.

The process of cotton production and development is essential for yield formation (Dong et al., 2012; Ai and Ma, 2020; Zhang et al., 2020; Wang et al., 2021). In several intercropping patterns, different intercropping patterns have little effect on the early growth and development of cotton (Sun et al., 2014). Intercropping will reach the flowering stage 0–2 days ahead of schedule, and boll opening 2–4 days ahead of schedule in Dongping County. In Xiajin, intercropping modes delay reaching the sowing stage by 1–3 days, squaring by 2 days, flowering by 5–8 days, and seed pod opening by 3 days. The whole growing cycle of cotton in Dongping County is 7–25 days shorter than in Xiajin

TABLE 3 | Cotton reproductive organs biomass (ROB) and vegetative organs biomass (VOB) accumulation in 2018.

Location	Trt	Squaring		First flowering		Full flowering		Full bolling		Boll opening	
		ROB	VOB	ROB	VOB	ROB	VOB	ROB	VOB	ROB	VOB
Dongping	M	8.23	188.79	140.39	557.45	197.97	473.96	99.76	333.91	602.88	352.94
	F2:4	6.41	206.74	43.00	237.86	122.24	375.89	271.07	574.06	306.50	414.97
	F4:4	4.86	183.59	66.15	385.68	168.13	518.78	166.58	480.91	280.65	213.42
	F4:6	3.10	186.22	103.20	526.27	201.34	503.79	175.96	503.32	332.22	242.58
	R2:4	6.75	215.11	44.28	247.44	124.73	394.86	284.77	591.47	315.82	431.71
	R4:4	5.13	189.13	68.85	405.18	176.64	539.77	171.64	495.49	294.83	219.90
	R4:6	3.17	191.89	106.31	542.20	207.42	524.18	181.30	518.58	338.90	252.37
Xiajin	**LSD**	**1.11**	**19.32**	**16.52**	**23.26**	**21.92**	**25.62**	**23.56**	**30.23**	**27.36**	**24.88**
	M	8.71	196.42	146.06	602.47	206.00	493.13	105.83	347.41	651.61	381.49
	F2:4	6.88	223.48	44.75	254.66	130.88	402.48	284.77	620.43	328.17	435.96
	F4:4	5.20	194.73	70.13	412.94	180.01	560.69	173.33	500.35	303.33	224.22
	F4:6	3.24	197.50	110.49	568.79	217.61	544.50	190.21	544.02	359.08	252.37
	R2:4	7.02	232.53	46.98	267.42	132.29	410.78	302.05	615.37	341.33	462.22
	R4:4	5.40	200.60	72.36	421.58	185.55	567.04	182.04	530.52	306.70	228.81
	R4:6	3.44	203.50	113.80	564.14	219.97	561.23	192.30	539.50	352.60	262.56
	LSD	**1.32**	**18.65**	**17.25**	**24.11**	**26.82**	**19.45**	**35.61**	**22.64**	**25.45**	**18.99**

Values followed by the same letters indicate non-significance difference among treatments within years at P < 0.05 (LSD test).

TABLE 4 | Cotton reproductive organs biomass (ROB) and vegetative organs biomass (VOB) accumulation in 2019.

Location	Trt	Squaring		First flowering		Full flowering		Full bolling		Boll opening	
		ROB	VOB	ROB	VOB	ROB	ROB	VOB	ROB	VOB	ROB
Dongping	M	8.65	213.58	151.74	625.02	213.96	488.32	103.79	371.01	669.87	370.77
	F2:4	7.32	213.01	48.64	245.07	138.29	421.45	282.02	649.44	352.94	456.89
	F4:4	5.50	211.41	68.82	424.63	174.93	550.22	174.99	505.20	320.34	243.61
	F4:6	3.48	195.63	116.75	558.17	209.48	519.06	183.07	528.74	359.06	259.74
	R2:4	7.02	221.63	49.20	272.44	133.55	414.80	313.53	609.40	360.48	475.32
	R4:4	5.39	200.59	77.89	454.30	190.91	583.39	195.92	540.54	303.76	228.79
	R4:6	3.62	211.28	121.34	558.63	226.27	593.01	188.62	570.96	359.44	262.57
	LSD	**1.20**	**18.45**	**16.52**	**22.75**	**23.50**	**19.03**	**27.55**	**26.70**	**26.13**	**23.09**
Xiajin	M	9.94	204.35	154.91	675.50	230.97	552.90	121.87	393.02	704.27	396.90
	F2:4	7.86	230.25	48.37	272.67	144.10	463.46	304.90	645.50	338.11	502.02
	F4:4	5.62	224.23	80.75	450.48	205.47	589.01	189.09	530.68	315.59	237.81
	F4:6	3.60	215.45	122.77	603.27	237.39	615.99	201.73	593.48	377.22	265.12
	R2:4	7.87	258.36	53.15	302.54	138.97	448.13	338.66	646.45	379.26	480.89
	R4:4	5.73	206.68	83.32	451.39	198.67	624.32	209.62	578.75	325.29	249.61
	R4:6	3.89	228.17	129.89	649.61	233.30	600.92	219.49	610.34	366.85	286.43
	LSD	**1.09**	**22.3**	**18.64**	**21.78**	**29.12**	**23.85**	**26.47**	**28.04**	**27.91**	**24.65**

The unit of biomass accumulation is g m^{-2}.

County (**Table 1**), so the biomass accumulation in Dongping County was lower than that in Xiajin County, and the yield was increased by 25.92–56.8% lower than in Xiajin County (**Table 2**).

In previous studies, several cotton–peanut intercropping methods were found to have a greater impact on cotton yield than others (Singh and Ahlawat, 2014; Singh et al., 2015). Cotton–peanut intercropping under conventional fertilization enhanced seed cotton production by 16.9% when compared to monoculture (Meso et al., 2007; Singh et al., 2015). Cotton and peanut are complementary in terms of time and space, as well as in terms of growth and development. Peanuts grow quickly and have a brief growth phase, but cotton grows slowly in the early stages (Sharma and Mathur, 2006). Peanut had podded and formed a yield before cotton reached

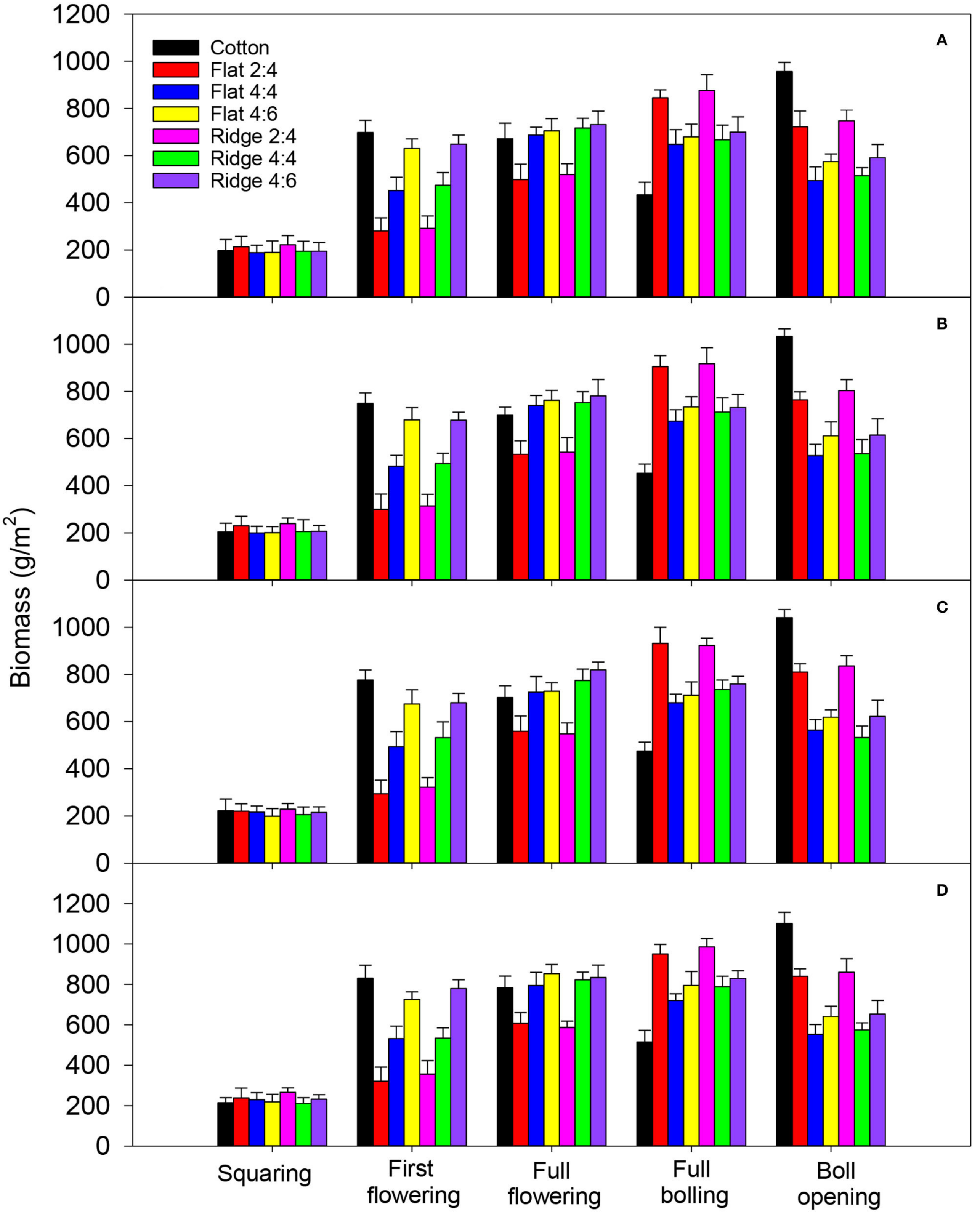

FIGURE 1 | Cotton biomass accumulation from 2018 to 2019 [**(A)** 2018, Dongping; **(B)** 2018, Xiajin; **(C)** 2019, Dongping; **(D)** 2019, Xiajin].

TABLE 5 | Cost and benefit of cotton production in 2018 and 2019.

Location	Trt	Seed	Sow	Intertillage	Fertilizer	Pesticide	Worker	Labor cost (yuan/worker)	Net income (yuan/mu)
		yuan/mu							
2018 Dongping	M	26.5	20	100	130	20	9	100	409.6
	F2:4	191.2	111.8	100	130	20	9	100	694.5
	F4:4	142.6	84.8	100	130	20	10	100	914.5
	F4:6	171.8	101	100	130	20	10	100	726.6
	R2:4	191.2	111.8	100	130	20	9	100	694.6
	R4:4	142.6	84.8	100	130	20	10	100	914.5
	R4:6	171.8	101	100	130	20	10	100	726.6
2018 Xiajin	M	27	20.8	100	130	20	10	100	422.0
	F2:4	197	116.3	100	130	20	10	100	708.0
	F4:4	148.4	89.1	100	130	20	11	100	942.2
	F4:6	178.7	103	100	130	20	11	100	763.3
	R2:4	198.9	117.4	100	130	20	10	100	715.0
	R4:4	145.5	86.5	100	130	20	11	100	942.2
	R4:6	177	106.1	100	130	20	11	100	763.3
2019 Dongping	M	26.5	20.5	100	130	20	9	100	409.6
	F2:4	191.2	111.8	100	130	20	9	100	694.7
	F4:4	142.6	84.8	100	130	20	10	100	914.5
	F4:6	171.8	101.6	100	130	20	10	100	726.6
	R2:4	198.9	116.3	100	130	20	9	100	722
	R4:4	149.8	86.5	100	130	20	10	100	933
	R4:6	177	106.1	100	130	20	10	100	741.3
2019 Xiajin	M	27.3	20.6	100	130	20	10	100	426.1
	F2:4	197	116.3	100	130	20	10	100	729.1
	F4:4	146.9	89.1	100	130	20	11	100	933
	F4:6	175.3	103	100	130	20	11	100	748.6
	R2:4	206.9	121	100	130	20	10	100	736.6
	R4:4	155.9	90	100	130	20	11	100	961.3
	R4:6	180.6	109.3	100	130	20	11	100	778.7

the phase of rapid accumulation, which had little effect on cotton yield, allowing cotton to make maximum use of light and heat resources. In addition, peanut nitrogen fixation can increase soil nitrogen, which is conducive to cotton growth (Singh and Ahlawat, 2015; Kumar et al., 2019; Xie et al., 2022).

The yield of lint cotton and seed cotton in Xiajin County in the past 2 years was the highest in F4:4, which was 30.0–34.1% higher than monoculture. Although the monoculture cotton yields were the highest in 2 years in Dongping County, the R2:4 lint yields were just 2.8–3.0% lower than the monoculture yield, indicating that the appropriate intercropping method had no effect on yield but was conducive to yield increase (Tang et al., 2021; Li L. et al., 2022). The improvement in the yield of intercropping was reflected in the influence of boll weight, lint percentage, and boll number per plant. At the full bolling stage, intercropping boosted biomass accumulation in reproductive organs by 178.0–202.1%, which aided in yield increase (**Figure 2**). Cotton–peanut intercropping can help to speed up the accumulation of nutrients in reproductive organs, as well as the growth and development of flowers and bolls and their settings (Wang et al., 2007; Liu et al., 2019; Maitra et al., 2020; Zhao et al., 2020). However, due to the longer growing period and larger biomass accumulation, Xiajin County's cotton production is higher than Dongping County's.

In field production, the purpose of intercropping is not only to increase the yield of crops but also to boost the economic benefits so as to obtain better benefits for cotton farmers (Dai et al., 2015; Wang et al., 2021). Cotton–peanut intercropping can boost cotton yield, improve field utilization rate, and provide greater production benefits, according to the results of a 2-year experiment. When compared to the net profit of monoculture, Dongping and Xiajin counties had the most economic benefit from adopting the R4:4 cotton method, which increased from 123.3 to 127.8% (**Table 5**).

CONCLUSIONS

In Dongping and Xiajin counties, different cotton intercropping patterns had substantial effects on cotton growth and development, cotton yield, yield components, biomass accumulation of different organs, and the cost and benefit of cotton production. The yield of lint cotton and seed cotton in Xiajin County in the last 2 years was the highest under F4:4,

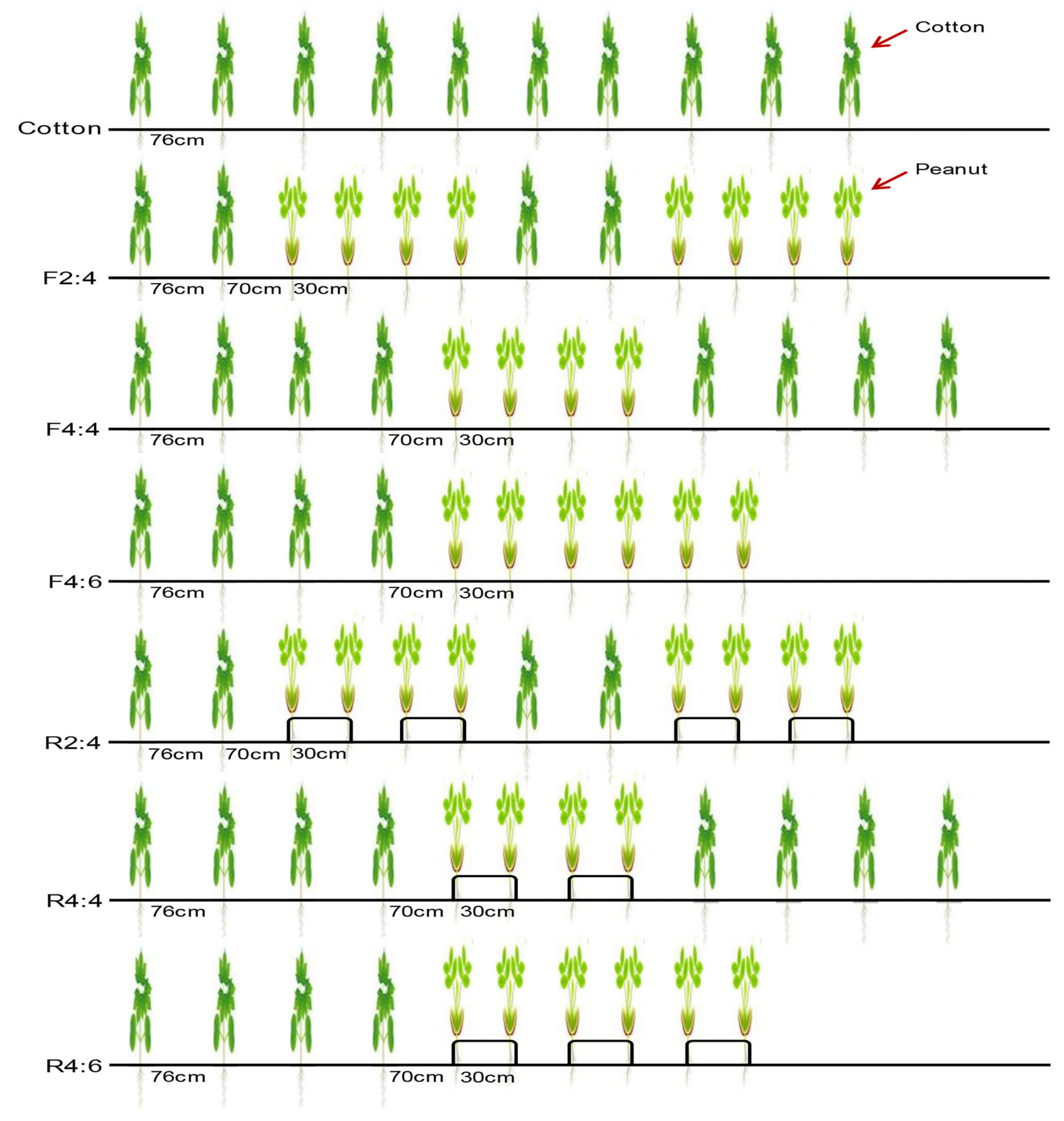

FIGURE 2 | Sketch of field experiments in cropping patterns.

while the yield of monoculture cotton in Dongping County was the highest. In Dongping County and Xiajin County, the economic benefits of F4:4 and R4:4 under various treatments were the highest in 2018, while the economic benefits of monoculture were the lowest. The economic benefit of R4:4 was the highest in Dongping and Xiajin counties in 2019, while the economic benefit of monoculture was the lowest. Based on the experiments between 2018 and 2019, we can select the best intercropping mode R4:4 that offers the highest production benefits in Dongping and Xiajin counties, which increased from 123.3 to 127.8% compared with the net profit of monoculture. The planting pattern is suitable for promotion in two counties.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

GW, DW, and SS: conceptualization. XZ, LW, SF, GW, SS, and DW: collecting data. MA, SS, RS, and XZ: methodology. SS, DW, and SF: writing—original draft. LW and SF: writing—review and editing. All authors contributed to the article and approved the submitted version.

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