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RESEARCH PAPER

Revealing seeding combinations of chili with brinjal, radish and coriander in a mixed cropping system to increase the productivity and profitability in Char ecosystem of subtropical climate

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Abstract

Mixed cropping is an important cropping system in char areas without an optimum seeding combination of chili, brinjal, radish and coriander. To identify this an experiment was conducted in two consecutive years to find suitable seeding ratio and to ensure maximization of yield and economic returns. The experiment was designed in a randomized complete block design with three replications. Four mixed cropping ratios with one sole chili viz. Chili (sole), 100% chili + 70% brinjal + 20% Radish + 10% coriander, 100% chili + 50% brinjal + 30% radish + 20% coriander, 100% chili + 30% brinjal + 40% radish + 30% coriander, 100% chili + 80% brinjal + 70% radish + 50% coriander were evaluated. The highest chili equivalent yield 29.9 t ha^{-1} (29.7 t ha^{-1} in 2019–20 and 30.1 t ha^{-1} in 2020–21), gross return (10512 USD ha^{-1}) and gross margin (9233 USD ha^{-1}) was found from 100% chili + 30% brinjal + 40% radish + 30% coriander seeding ratio. On the other hand, the lowest chili equivalent yield 11.8 t ha^{-1} (11.7 t ha^{-1} in 2019–20 and 11.9 t ha^{-1} in 2020–21), gross return (4167 USD ha^{-1}) and gross margin (2845 USD ha^{-1}) was found from Chili (sole) treatment. The maximum MBCR (241.7) was also recorded from the same 100% chili mixed cropped with 30% brinjal+ 40% radish + 30% coriander seeding combination. Finally, the combination of 100% chili + 30% brinjal + 40% radish + 30% coriander seeds has found great productivity and profitability in mixed cropping system.

Keywords

Mixed cropping, chili, brinjal, radish, coriander, productivity and profitability

Introduction

Mixed cropping, often referred to as polyculture, inter-cropping, or co-cultivation, is the process of planting two or more plants simultaneously in the same area and interdigitating them so that they grow together. But single crop systems have steadily supplanted mixed cropping (Clara et al. 2020). The aims of crop combinations are to obtain cash returns in manageable installments, particularly for irrigated crops; to improve labor distribution throughout the year; to make the best use of the space and nutrients that are available; to protect against weather, disease, and pest risks; to provide for daily needs like pulses, fiber, and oil seeds; and to obtain balanced cattle feed (Kumar et al. 2021).

Char ecosystem is a unique environment that demands unique solutions. The chars are riverine islands that are formed by the deposition of sediment carried by rivers.

In Bangladesh's history, environment, economy, and social life, chars have a special significance (Zaman and Alam 2021). The people living in chars are often marginalized and have limited rights to land and livelihood resources (Zaman and Alam 2021).

A common agricultural practice in Bangladesh is mixed cropping, especially in the char ecosystem. The simultaneous cultivation of two or more crops on the same piece of land has several advantages (Karim et al. 2017; Rahman et al. 2021). It is one of the adaptation measures adopted by char dwellers to cope with hazards such as floods, erosion, droughts, hailstorms, and cold waves. It increases output and ensures the farmer has access to food while reducing the spread of illnesses and pests. Legumes can also increase soil fertility by supplying nitrogen to the soil. This method also improves crop output and reduces soil erosion. The general idea is that growing many crops at once conserves land because they may ripen at different times in the same field and has many positive environmental effects. A dense plant stand results in a higher number of plants per unit area; the foliage and roots cover a larger area, increasing radiation (Keating and Carberry 1993), water (Morris and Garrity 1993a), and nutrient capture (Midmore 1993; Morris and Garrity 1993b); the balance of input and outgo of soil nutrients; the suppression of weeds and insect pests; the resistance of the plant to climate extremes (wet, dry, hot, and cold); the suppression of plant diseases; the increase in overall productivity; and the reduced workload associated with farming operations, which enables equal attention to be given to all crops (Sarker et al. 2022).

For small-scale farming where harvesting is done by hand, mixed cropping works well. The method has been effectively used to increase small farmers' revenue and food production while reducing the possibility of a complete crop failure since even in the event of a failed crop, other crops in the field may still yield. In comparison to monoculture farming, mixed cropping also uses less nutritional inputs, such as irrigation, fertilizers, pruning, and insect management. As a result, it is frequently more economical.

Because two or more distinct crops are grown concurrently in the same area, mixed cropping lowers the probability of total crop failure. Compared to planting solitary crops, a successful mixed cropping system offers superior resource usage efficiency, varied crop output, and a higher financial return overall production per unit area. Farmers commonly mixed diverse crops like chili, brinjal, radish, and coriander with other leafy vegetables in the char ecosystem. But regrettably, when they sow seeds, they don't use the proper seed-to-soil ratio. Only they use their own assumptions, and each farmer has a different one. As a result, the farmers reap a variety of benefits from their land. They don't know what the ratio is for mixed cropping. Therefore, the ultimate objective of the current study is to determine the best-mixed cropping combinations of coriander, radish, chili, and brinjal while also ensuring that the land is used to its full potential for maximum yield and profit.

Materials and methods

Description of the experimental site

To test the agronomic performance of a mixed crop of chili, brinjal, radish and coriander, a field experiment was carried out at a farmer's field in Chinirpotol, Saghata, Gaibandha of Bangladesh (25°09'N, 89°57'E and 18 m above sea level) under the agro-ecological zone, AEZ-7 (Active Brahmaputra-Jamuna Floodplain) during the rabi seasons of 2019–20 and 2020–21, and to maximize higher yield and financial return. The experimental sites were situated in a subtropical climate zone, which was characterized by low annual rainfall (5–142 mm) from November to May, while crops were growing. The average monthly low temperature was 11.1–22.6 °C, while the average monthly maximum temperature was from 21.7–33.3 °C (Fig. 1). The soil at the trial site consisted of silty alluvium and sand, with a high content of weatherable minerals and a somewhat acidic reactivity (FRG 2018). The soil's organic

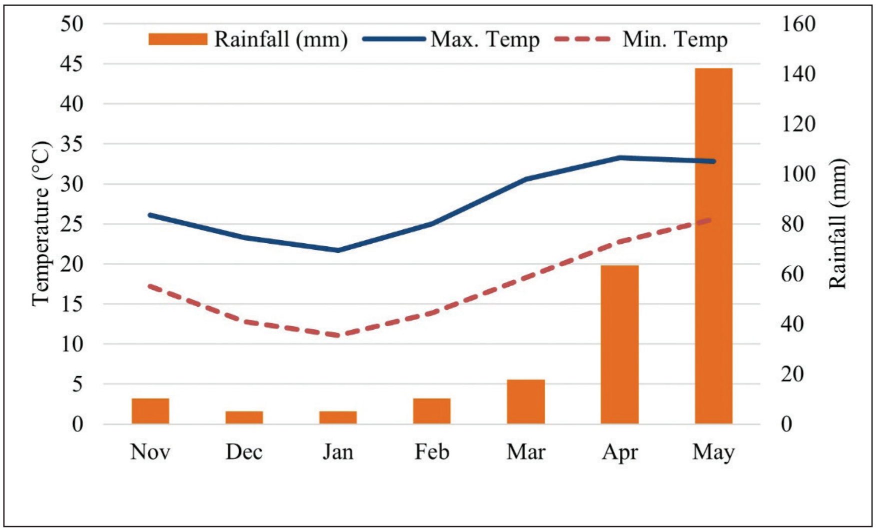

Figure 1. Description of the Experimental Site.

Table 1. Initial soil status of the experimental site.

	pH	OM (%)	Total N (%)	K	P	S	Zn	B
				meq/100 g	µg/g soil			
Value	6.5	0.78	0.05	0.12	9.60	14.9	0.23	0.24
Interpretation	Slightly acidic	VL	VL	L	L	M	VL	L

* VL = very low, L = low, M = medium.

matter content was extremely low, nitrogen was scarce, and the levels of K, S, Zn, and B varied from very low to medium (Table 1).

Selection of crops and experimental design

Main crop: Chili (*Capsicum frutescens* L.) is typically grown by farmers in char areas because of its desired output and reasonable pricing. It was discovered that among char dwellers, chili cultivation is a significant source of revenue. For this reason, chili was chosen as the primary crop.

Subsidiary crops: Brinjal (*Solanum melongena* L.) is a very important vegetable crop grown widely in char areas. It is also a high value crop and farmers can easily earn more from it. Radish (*Raphanus sativus* L.) is a fast-growing vegetable, grown in char areas. Besides, Coriander (*Coriandrum sativum* L.) leaf is a high value spice crop grown in char areas. A mixed crop of brinjal, radish and coriander are profitable and can easily be grown simultaneously with chili. So, chili, radish and coriander were used as subsidiary crops.

Three scattered replications and a randomized complete block design were used to set up the experiment.. The unit plot size was 6 m × 6 m. Farmers of char ecosystem usually use the seeding rate of chili (7 kg ha^{-1}), brinjal (1 kg ha^{-1}), radish (2 kg ha^{-1}) and coriander (4 kg^{-1}) in the mixed cropping system. Keeping this in mind, we calculated the percentage based on seed rate. As for example; 100% chili+ 70% binjal+20% radish+10% coriander means 7 kg chili, 700 g brinjal, 400 g radish and 400 g coriander seed were sown together. Therefore, four seeding combinations viz. 100% chili + 70% brinjal + 20% Radish + 10% coriander, 100% chili + 50% brinjal + 30% radish + 20% coriander, 100% chili + 30% brinjal + 40% radish + 30% coriander and 100% chili + 80% brinjal + 70% radish + 50% coriander along with Chili (sole) were evaluated. The varieties of chili, brinjal, radish and coriander were BARI Morich-3, BARI Hybrid begun-4, BARI Mula-1 and BARI Dhania-1, respectively.

Crop management

Seeds of all crops were mixed and sown on November 15–20 of each year. The fertilizer doses were N-P-K-S-Zn-B @ 142-58-61-18-3-2 kg ha^{-1}, respectively, in all the treatments. A full dose of P, S, Zn, and 1/4th of K was applied during final land preparation. The remaining 3/4thK and full dose of N were divided into 3 equal splits and applied 25, 50, and 75 days after sowing. Weeding and thinning were done two to three weeks after seeding. The crop was irrigated 5–6 times each year. Brinjal shoot and fruit borer (BSFB) was attacked that was controlled by Spinosad (Tracer 45SC®, Auto Crop Care Limited, Bangladesh) @ 0.4 ml L^{-1} of water. Chili plant was also attacked by thrips which controlled by Imidacloprid (Admire 20SL®, Bayer Crop Science Limited, Bangladesh) @ 0.5 ml L^{-1} of water. Radish was the first harvested crop after one month of sowing (15–20 December) as a leafy vegetable; after that, coriander leaf was harvested within two months after sowing (15–20 January). After the harvest of radish and coriander, chili and brinjal remain together in the field. The chili started to be harvested on 1 March and continued up to 31 March in both years. After one chili harvest, the plants became slightly thin; in the meantime, brinjal got more space and started to fruit. Even after the chili harvest, brinjal remains two months longer in the field. The brinjal harvest commenced on 15 March and continued up to 31 May.

Observations

Crop yield

Crop yield was determined from an area of 9 m^2 (3 m × 3 m) in the center of each plot and converted to t ha^{-1}.

Chili equivalent yield

The chili equivalent yield (CEY) of brinjal, radish, and coriander was calculated from the yield and price of each crop using the formula:

$$CEY\ (crop_x) = Y_x\ (P_x/P_c)$$

where Y_x is the yield of crop 'x' (t ha^{-1}), P_x is the price of crop 'x' (USD t^{-1}), and P_c is the price of chili (USD t^{-1}). The prices of chili, brinjal, radish, and coriander leaf used were USD 354, 236, 118, and 708 t^{-1}, respectively. The values were calculated based on the farmgate price in Bangladeshi Taka (BDT), which was converted to USD using 1 USD = 84.77 BDT (average exchange rate from 2019 to 2021).

Financial return

The costs of tillage, seed, sowing, human labor, fertilizers, pesticides, irrigation, and harvesting etc. were all considered variables in the analysis. Based on the prices charged by neighborhood service providers, the costs of irrigation and tillage were calculated. The amount of product harvested (t ha^{-1}) and their farm gate pricing were used to compute the gross return (GR) for each crop. The costs for chili, brinjal, radish, and coriander leaf were 354, 236, 118, and 708 USD t^{-1}, respectively. The difference between the gross return and the total variable cost (TVC) was used to determine the gross margin (GM) for each crop. The marginal benefit cost ratio (MBCR) is a financial metric that compares the change in benefits to the change in costs because of a specific activity or investment. The marginal value product (MVP) over the marginal value cost (MVC) was used to calculate the marginal benefit cost ratio (MBCR) using the formula:

MBCR = GR (mixed cropping) - GR (sole crop) / TVC (mixed crop) - TVC (sole crop)

Statistical analysis

Data were analyzed using ANOVA (in Crop Stat 7.2) to investigate differences between treatments, and the means were separated using least significant difference (LSD) at the 5% level of significance ($p < 0.05$).

Results

Yield of crops in a mixed cropping system

There was a significant yield variation of chili, brinjal, radish, and coriander among the different seeding combinations (Tables 2, 3). The maximum chili yield was observed in the Chili (sole) treatment with a value of 11.5 t ha^{-1} in 2019–20 and 11.9 t ha^{-1} in 2020–21 followed by 100% chili + 30% brinjal + 40% radish + 30% coriander combination (10.0 t ha^{-1} in 2019–20 and 10.5 t ha^{-1} in 2020–21) and lowest in 100% chili + 70% brinjal + 20% Radish + 10% coriander (7.50 and 7.45 t ha^{-1}) treatment. In the case of brinjal, the significant highest yield was recorded in the 100% chili + 30% brinjal + 40% radish + 30% coriander treatment (16.5 t ha^{-1} in 2019–20 and 16.83 t ha^{-1} in 2020–21) and the lowest in the 100% chili + 70% brinjal + 20% Radish + 10% coriander treatment (12.5 t ha^{-1} in 2019–20 and 12.67 t ha^{-1} in 2020–21). Similarly, in radish, the highest value was observed in the same 100% chili + 30% brinjal + 40% radish + 30% coriander treatment (10.0 and 10.33 t ha^{-1} in both years), next to the 100% chili + 80% brinjal + 70% radish + 50% coriander and 100% chili + 50% brinjal + 30% radish + 20% coriander treatments. The highest coriander yield was performed in the 100% chili + 30% brinjal + 40% radish + 30% coriander treatment (2.47 t ha^{-1} in 2019–20 and 2.50 t ha^{-1} in 2020–21), similar to the 100% chili + 50% brinjal + 30% radish + 20% coriander treatment, and the lowest in the 100% chili + 70% brinjal + 20% Radish + 10% coriander treatment (2.25 t ha^{-1} in 2019–20 and 2.00 t ha^{-1} in 2020–21).

Chili Equivalent Yield (CEY)

The highest chili equivalent yield was found in 100% chili + 30% brinjal + 40% radish + 30% coriander treatment (29.7 t ha^{-1} in 2019–20 and 30.1 t ha^{-1} in 2020–21), with an average of 29.9 t ha^{-1}, which was higher compared to all other treatments. The lowest chili equivalent yield was found from Chili (sole) cultivation (11.7 t ha^{-1} in 2019–20 and 11.9 t ha^{-1} in 2020–21, with an average of 11.8 t ha^{-1}). However, 100% chili + 30% brinjal + 40% radish + 30% coriander performed best with the highest 253% yield increase over sole crop of chili.

Financial return of mixed cropping (average of 2 years)

An analysis of the cost-return of mixed-crop chili with brinjal, radish, and coriander has been presented in Table 4. The highest gross return (10582 USD ha^{-1}) and

Table 2. Yield of different crops and chili equivalent yield (CEY) during 2019–20 in mixed cropping.

Treatments	Chili yield (t ha^{-1})	Brinjal yield (t ha^{-1})	Radish yield (t ha^{-1})	Coriander yield (t ha^{-1})	Chili equivalent yield (t ha^{-1})	% Yield increase over sole crop
Chili (sole)	11.50	-	-	-	11.7	-
100% chili + 70% brinjal + 20% Radish + 10% coriander	7.50	12.5	5.00	2.25	22.4	191
100% chili + 50% brinjal + 30% radish + 20% coriander	9.00	14.0	7.50	2.50	26.2	224
100% chili + 30% brinjal + 40% radish + 30% coriander	10.00	16.5	10.00	2.50	29.7	254
100% chili + 80% brinjal + 70% radish + 50% coriander	9.50	14.5	7.50	2.25	26.5	226
$LSD_{0.05}$	0.84	0.42	0.42	0.42	0.29	-
CV (%)	5.2	6.4	6.8	5.9	5.5	-

Table 3. Yield of different crops and chili equivalent yield (CEY) during 2020–21 in mixed cropping.

Treatments	Chili yield (t ha^{-1})	Brinjal yield (t ha^{-1})	Radish yield (t ha^{-1})	Coriander yield (t ha^{-1})	Chili equivalent yield (t ha^{-1})	% Yield increase over sole crop
Chili (sole)	11.85	-	-	-	11.9	-
100% chili + 70% brinjal + 20% Radish + 10% coriander	7.45	12.67	5.33	2.00	21.7	182
100% chili + 50% brinjal + 30% radish + 20% coriander	9.17	14.08	7.83	2.26	25.7	216
100% chili + 30% brinjal + 40% radish + 30% coriander	10.50	16.83	10.33	2.47	30.1	253
100% chili + 80% brinjal + 70% radish + 50% coriander	9.83	13.50	8.50	2.42	26.5	223
$LSD_{0.05}$	1.32	1.31	0.63	0.28	1.83	-
CV (%)	7.2	6.8	8.1	8.5	6.6	-

Table 4. Financial return of different ratios of mixed cropping used in the experiment (average of 2 years) (1 USD = 84.77 BDT).

Treatments	Gross return (USD ha^{-1})	Total variable cost (USD ha^{-1})	Gross margin (USD ha^{-1})	MBCR
Chili (sole)	4167	1322	2845	-
100% chili + 70% brinjal + 20% Radish + 10% coriander	7798	1358	6440	100.6
100% chili + 50% brinjal + 30% radish + 20% coriander	9180	1351	7829	173.4
100% chili + 30% brinjal + 40% radish + 30% coriander	10582	1348	9233	241.7
100% chili + 80% brinjal + 70% radish + 50% coriander	9378	1364	8014	122.7

gross margin (9233 USD ha^{-1}) were obtained from 100% chili + 30% brinjal + 40% radish + 30% coriander, followed by 100% chili + 80% brinjal + 70% radish + 50% coriander due to the performance of mixed cropping. The lowest gross return (4167 USD ha^{-1}) and gross margin (2845 USD ha^{-1}) were obtained from treatment Chili (sole). Finally, the maximum MBCR recorded from 100% chili + 30% brinjal + 40% radish + 30% coriander seeding combination in a mixed cropping system.

Discussion

Growing two or more crops together on the same land is especially true in char areas are known as mixed cropping in farming and has various benefits to practicing non-cereal mixed cropping (chili, brinjal, radish and coriander), that increased total production and profitability through reducing the risk of crop failure, increasing soil fertility, and maximizing land use efficiency (Rahman et al. 2021).

Data from the study revealed that the yield was increased by 191 to 254% and profitability was 126–225% more in mixed cropping system over the sole chili cultivation. The yield increase rate varied over the sole crop due to the number of crops involved in the mixed cropping system. The reason for higher yield in char areas is mainly due to the combination of more non-cereal crops (brinjal, radish and coriander) cultivated together. In a Mungbean and sesame mixed cropping system, yield improved by 1–13% and profitability increased by 12–22%, were reported by Ali et al. (2007). According to Muoneke et al. (2007), Ram and Meena (2014), inter/mixed cropping increases the system yield of component crops overall while reducing the probability of crop failure due to weather conditions.

When compared to a single crop, mixed cropping yields more because it is more resilient to disease and insect damage, maximizes soil nutrient usage, reduces weed pressure, and has a greater ability to hold water due to its larger area coverage (Valentín et al. 2008). Furthermore, pests and diseases may not affect all crops equally. Also, certain crops could ward off pests and illnesses that harm other crops.

Mixed cropping also helps to increase soil fertility by reducing soil erosion and improving soil structure of the char areas (Lalotra et al. 2022). This is because different crops have different root systems that help to hold the soil together and prevent erosion. Because various crops have distinct root systems, soil erosion can be avoided, and soil structure can be improved. Deep-rooted crops have the potential to enhance water infiltration and loosen compacted soil. We found that while radish has a shallow root system whereas chili, brinjal and coriander have deep root systems. In that instance, radish typically absorbs nutrients from the upper soil level, while coriander, chili, and brinjal absorb nutrients from the deeper soil layer and break down the soil layer, which increases the pace at which water infiltrates the soil.

Farmers who practice mixed cropping may have access to a wider variety of crops to sell, so reducing their reliance on a single crop. Studies have revealed that mixed cropping has a number of benefits over sole cropping, including the complementary use of growth factors like soil nutrients, a decrease in the need for costly fertilizers and pesticides, light, water, a decrease in the incidence of pests and diseases, suppress weed pressure, decrease in soil erosion, a higher production of total biomass, more yield stability, sustainable intensification and increased household food security(Ram and Meena 2014; Dharam and Shankar 2016; Weltzien and Christinck 2017; Clara et al. 2020; Lalotra et al. 2022). Additionally, mixed cropping helps to maximize land use efficiency by allowing farmers to grow multiple crops on the same plot of land. An approach for optimizing resource use, mixed cropping regulates natural entities, lowers the chance of crop failure in unfavorable climates, and harnesses the synergistic interactions of biological components. It is important to keep in mind the following when selecting component crops for mixed cropping: crops should have different rooting depths, better leaf orientation, host specificity for pests, peak nutrient and water demands, different rooting behaviors, and less competition from other crops (Seran and Brintha 2010). Many family and root system crops were available for us to choose from during our investigation.

Finally, we can say, because of their extreme vulnerability to natural disasters (such hailstorms, cold waves, droughts, floods, and erosion) char areas have a significant impact on agriculture. Practicing of mixed cropping system helps to reduce these risks in char agriculture due to its ability to diversify farmers' sources of income and lessen the impact of crop failure.

Conclusion

With a seeding ratio of 100% chili + 30% brinjal + 40% radish + 30% coriander, the greatest chili equivalent yield of 29.9 t ha^{-1} (29.7 t ha^{-1} in 2019–20 and 30.1 t ha^{-1} in 2020–21), gross return (10512 USD ha^{-1}), and gross margin (9233 USD ha^{-1}) occurred. On the other hand, the Chili (single) treatment yielded the lowest equivalent yield of chili (11.8 t ha^{-1}; 11.7 t ha^{-1} in 2019–20 and 11.9 t ha^{-1} in 2020–21), as well as the lowest gross margin (2845 USD ha^{-1}). After two years of research, it can be said that 100% chili mixed with 30% brinjal, 40% radish, and 30% coriander yielded the highest crop and system yield and the best economic performance when compared to Chili (sole) cultivation. Make sure the subsidiary crop does not hinder the main crop's growth or mature before or after the main crop in order to get the most advantage from it blended with it. In conclusion, mixed cropping of coriander, radish, brinjal, and chili is a profitable and productive cropping system in the subtropical climate's char ecosystem.

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