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Evaluation of *Rabi* Maize-based Intercropping System for Augmenting the Productivity and Profitability of *Rabi* Maize under Irrigated Conditions of Bihar

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ABSTRACT

Background: A combination of maize and legume, cabbage and potato in intercropping benefits the agricultural production system due to different peak period of growth and synergistic effects, which reflected into yield advantage. In order to reduce nutritional competition and the yield gaps between actual production and production potential for both crops in the intercropping system, more information is required for the optimization of maize-based intercropping systems. So, keeping above fact in mind, the present study was undertaken to find out the suitable *rabi* maize based intercropping system for augmenting productivity and profitability of maize.

Methods: A field experiment was conducted on the farmer's field of selected villages of KVK Bhagalpur (on-farm trials) during the winter (*rabi*) season of 2020-21 and 2021-22 on *rabi* maize to validate, refine and popularize the technology developed at Bihar Agricultural University, Sabour, Bhagalpur (Bihar) and ICAR-Indian Institute of Maize Research (IIMR), Ludhiana, for enhancing the productivity and profitability of *rabi* maize. The experiment, comprising four treatments, *viz.,* sole *rabi* maize (farmer's practice), maize + potato (1:1 row ratio), maize + vegetable pea (1:2 row ratio) and maize + cabbage (1:1 row ratio), was arranged in a randomized block design (RBD) with five replications. All five farmers selected for experimentation were treated as replications.

Result: Experimental results revealed that all three intercropping associations of maize + vegetable pea (1:2 row ratio), maize + potato (1:1 row ratio), maize + vegetable pea (1:2 row ratio) and maize + cabbage (1:1 row ratio) produced significantly higher maize equivalent yields than the sole crop of *rabi* maize. However, among the intercropping systems, maize + vegetable pea (1:2 row ratio) produced the highest maize equivalent yield (241.0 q/ha) and significantly incurred the highest net return (322093 ` /ha), as well as a higher B: C ratio (6.04) than the rest of the intercropping systems as well as sole crop of *rabi* maize.

Key words: Cabbage, Intercropping, Maize equivalent yield, Maize, Potato, Vegetable pea.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop of the world after rice and wheat (Arya *et al.,* 2015 and 2020). With a production of 1162.3 million metric tons and a productivity of 5.75 t/ha, maize is cultivated on 201.98 million hectares around the world. The world's maize production has increased from 11 million metric tons in 2020–21 to 12.1 million metric tons in 2021-22 (ICAR–IIMR, 2022). India is the fourth largest producer of maize in the world in terms of total maize output, with an area of 9.89 m ha, production of 31.65 m tons and productivity of 3199 kg/ha (ICAR-IIMR, 2022). In Bihar, generally 70-80% maize is grown during the *rabi* season, which occupies an area of 0.46 million ha with production and productivity of 1.9 million metric tons and 40.81 q/ha, respectively (Anonymous 2021).

The intercropping system involves growing two or more crops concurrently on the same plot of land while maintaining a distinct row pattern (Ouma and Jeruto, 2010). It is typically used on small farms with few resources by small and marginal farmers and it has been seen to increase yields with greater stability in a variety of crop combinations (Maitra *et al*., 2021). Additionally, intercropping systems are known for their more effective use of water, land, nutrients and inputs such as fertilizers, plant protection chemicals, labor

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and reduction in weeds, resulting in healthy, safe and high-quality food produced in an environmentally friendly manner. (Awal *et al*., 2006). In addition to improving production stability, it also raises overall productivity and income per unit of land area. The vegetable pea is a significant legume crop and the main plant protein source for both humans and animals. Garden peas are a high-value, short-season (60-70 days), high-return crop that can be planted in the *rabi* season to increase cropping intensity without affecting maize growth and yield. Due to the low temperature at that time, the rate of *rabi* maize seed germination and plant growth is very low. The space between two rows of maize at an early stage may be utilized by planting of any short duration with dwarf nature crops as intercrops. Contrarily, maize is a long-lasting, widely spaced crop that matures in about 5 months and offers opportunities for intercropping for a quick return. A combination of maize and legume, cabbage and potato in intercropping benefits the agricultural production system due to different peak period of growth and synergistic effects, which reflected into yield advantage. In order to reduce nutritional competition and the yield gaps between actual production and production potential for both crops in the intercropping system, the present study was undertaken to find out the suitable *rabi* maize based intercropping system for augmenting productivity and profitability of maize.

MATERIALS AND METHODS

Field experiments (on-farm trials) were conducted on *rabi* maize-based intercropping during the winter (*rabi*) seasons of 2020-21 and 2021-22 at farmer's fields in three villages of Bhagalpur, Bihar, to validate, refine and popularize the technology developed at Bihar Agricultural University, Sabour, Bhagalpur (Bihar) and ICAR-Indian Institute of Maize Research (IIMR), Ludhiana, for enhancing the productivity and profitability of *rabi* maize-based cropping systems. A Participatory Rural Appraisal (PRA) was conducted to determine the root causes of the high production costs and low profit margins associated with *rabi* maize. The soils of the experimental plot was loam to clay loamy in texture, with average pH 7.5, organic carbon 0.39%, available N 201.0 kg/ha, available P_2O_5 20.5 kg/ha and available K_2O 218.7 kg/ha. The fields with a similar cropping pattern of rice as the preceding crop in the previous season were selected for conducting the experiment to follow the homogeneity test. The experiment, comprising four treatments, *viz.,* sole *rabi* maize (farmer's practice), maize + potato (1:1 row ratio), maize + vegetable pea (1:2 row ratio) and maize + cabbage (1:1 row ratio), was arranged in a randomized block design (RBD) with five replications. All five farmers selected for experimentation were treated as replications. The unit plot size was 10 m × 10 m. The maize crop as well as all intercrops were sown in the third week of November after the harvest of rice during both years at a spacing of 45 × 15 cm and 60 × 25 cm for the sole crop and intercrops, respectively. Maize + potato and maize + vegetable pea were sown on a fresh raised bed and sole *rabi* maize and maize + cabbage were sown or transplanted on a flat bed. The maize crop was grown as an additive series (100 percent of its recommended population in pure stand) as the base or sole crop. Intercrops like potato, vegetable pea and cabbage were introduced into the base crop by adjusting or changing crop geometry. The maize crop, either alone or under intercropping of maize + potato, maize + vegetable pea and maize + cabbage, was fertilized with 150:75:75 N:P_2O_5:K_2O kg/ha and applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). Half the dose of N and the full dose of P_2O_5 and K_2O were applied as basal and the remaining half dose of N was applied as top dressing in two equal splits at knee height and tasseling initiation stages of the maize crop. Additionally, no extra nutrients were added to the intercrops. For healthy maize and intercrops, all advised cultural practices were followed. Based on the minimum support price or the current market rate of the products, the maize-equivalent yield and monetary values of crops were calculated. In order to determine the economic variability of each cropping pattern, a benefit-cost ratio (BCR) analysis was also done. The benefit-cost ratio (B: C ratio) was expressed as the ratio of net returns to the cost of cultivation.

RESULTS AND DISCUSSION

Effect of intercropping on growth, yield attributes and yield of maize

The growth and yield attributing characters of maize, *viz.,* plant height, dry weight, number of grains per cob, cob length, cob girth and 1,000-seed weight, were significantly influenced by the involvement of various intercrops with *rabi* maize (Table 1). Maximum plant height (205.8 cm), dry weight (295.8 g), number of grains/cob (457.5), cob length (13.90 cm), cob girth (10.11 cm) and 1,000-seed weight (253.8 g) were recorded under the sole crop of maize, which was statistically at par with all intercrops, *i.e.,* maize + potato (1:1 row ratio), maize + vegetable pea (1:2 row ratio), except maize + cabbage (1:1 row ratio). It was also recorded that the sole crop being statistically at par with maize + vegetable pea and maize + potato produced the highest grain yield of maize (93.5 q/ha) than maize + cabbage, which gave the minimum grain yield (88.1 q/ha). The yield of intercrops was reduced significantly when compared to their respective sole maize crop. The results are in confirmation with the findings of Sultana *et al.* (2013) in maize + legumes in intercropping and Shweta *et al.* (2022) in various maize cropping systems. Among the intercrops, maize + vegetable pea gave the maximum grain yield of maize (92.7 q/ha). The higher grain yield in maize under the maize + vegetable system might be due to the synergistic effect of vegetable pea with maize or minimum crop competition; however, the reduction in grain yield of maize under maize + cabbage intercropping may be due to more crop competition of cabbage with maize intercropping. Similar results were also observed by Singh

et al. (2000) and Mishra *et al.* (2001), Pawar *et al.* (2011), Sarker *et al.* (2013), Khanum *et al.* (2019), Hashim *et al*. (2015), Landschoot *et al*. (2024), Begam *et al.* (2024), Li *et al.* (2023), Talukdar *et al.* (2022), Sahoo *et al.* (2024), Singh *et al.* (2023), Prakash *et al.* (2024) and Panda *et al.* (2021). Maize + vegetable pea (1:2 row ratio; maize planted at 60 × 25 cm) produced more grain yield as compared to other intercrops with maize, probably due to the sharing of biologically fixed nitrogen by legumes with maize (Maitra and Ray, 2019). Despite the general trend of reduced maize yield in intercropping scenarios our study highlights the potential for higher total system yields in intercropping compared to monocultures. A similar trend was also observed for stover yield.

Yield of intercrops

The yield of various crops showed variations under different intercropping combinations with *rabi* maize (Table 2). The highest intercrop yield (196.4 q/ha) was recorded from potato under maize + potato intercropping combination (1:1 row ratio, maize planted at 60 × 25 cm), followed by maize + cabbage (182.3 q/ha) and maize + vegetable pea (85.3 q/ha) intercropping combination. Landschoot *et al*. (2024), Begam *et al.* (2024), Li *et al.* (2023), Talukdar *et al.* (2022), Sahoo *et al.* (2024), Singh *et al.* (2023) and Prakash *et al.* (2024) also reported the similar results.

Effect of inter crops on maize equivalent yield

In comparison to sole maize, all intercropping combinations produced higher maize equivalent yields. Among the intercrops, the highest maize equivalent yield (241.0 q/ha) was obtained from maize + vegetable pea, followed by the maize + potato intercrop combination (Table 2). However, the lowest maize equivalent yield (166.4 q/ha) was obtained from the maize + cabbage intercropping combination. The higher maize equivalent yield in the maize + vegetable pea intercrop was due to the higher market price of vegetable pea as compared to other intercrops. Maize as a wider-spaced plant offers some crops with intercropping combinations to grow together without economic loss, sacrificing a small maize yield for greater total production in respect of land and time. This practice offered considerable yield advantages and a higher economic return over sole cropping because of its efficient utilization of growth resources (Faruque *et al.,* 1996). This is attributed to more efficient resource utilization and land use (Li *et al*., 2020). The 'legume effect', enhancing nitrogen nutrition and reducing weed competition in intercropping systems was evident (Landschoot *et al*., 2024). Similar results were also reported by Khanum *et al.* (2019) in maize and cabbage intercropping combinations.

Economics

Economic analysis is an important tool to evaluate the economic feasibility of intercropping systems. Economic analysis of the various intercropping systems revealed that the gross returns, net returns and B: C ratio was all significantly impacted by the various intercropping systems (Table 2). Compared to the sole crop of maize, every intercrop produced higher gross returns, net returns and B: C ratios. The maize + vegetable pea, maize + potato and maize + cabbage intercropping incurred 156.3%, 128.6% and 93.6% higher gross returns than sole *rabi* maize, respectively. Among the three intercropping systems, maize and vegetable pea intercropping had the highest gross income (` 386098/ha), net return (` 322093/ha) and B:C ratio (6.04). This could be attributed mainly to the higher maize equivalent yield with intercropping. Sannagoudar

Table 1: Growth, yield attributes and yield of *Rabi* maize as influenced by various intercropping components (Mean of two years data).

Technology option	Plant height (cm) at harvest	Dry wt./plant (g) at harvest	Yield attributes				Yield (q/ha)	
			Grains/ cob	Cob length (cm)	Cob girth (cm)	1000-grain wt. (g)	Grain	Stover
Sole maize	203.4	295.8	457.5	13.90	10.11	253.8	93.5	117.8
Maize + Potato	200.0	271.0	421.6	13.07	9.68	239.0	91.9	109.4
Maize + Vegetable pea	205.8	288.5	427.0	13.41	9.75	248.6	92.7	111.4
Maize + Cabbage	186.5	268.0	411.6	11.65	8.47	235.8	88.1	101.0
SEm±	5.22	7.09	13.43	0.73	0.41	10.73	1.51	3.1
CD (P=0.05)	15.1	20.5	38.8	2.10	1.18	31.00	4.37	9.00

Table 2: Influence of various intercropping on yield and economics of *rabi* maize (Mean of two Years data).

Treatment	Maize yield (q/ha)	Intercrop yield (q/ha)	Maize equivalent yield (q/ha)	Cost of cultivation (`/ha)	Gross return (`/ha)	Net return (`/ha)	B: C ratio
Sole maize	91.60	-	91.6	43065	150637	107572	2.50
Maize + Potato	89.39	196.4	212.2	80525	344358	263833	3.28
Maize + Vegetable pea	89.15	85.3	241.0	64005	386098	322093	5.03
Maize + Cabbage	85.07	182.3	166.4	59285	267526	208241	3.51

et al. (2021), Singh *et al.* (2022a), Singh *et al.* (2022b) and Verma *et al.* (2021) also reported similar results from maize-based intercropping systems.

CONCLUSION

Among the intercropping systems, maize + vegetable pea (1:2 row ratio) produced the highest maize equivalent yield and significantly incurred the highest net return, as well as a higher B: C ratio than the rest of the intercropping systems as well as sole crop of *rabi* maize. Thus, on the basis of two years of findings, it may be concluded that the maize + vegetable pea (1:2 row ratio, maize planted at 60 × 25 cm) intercropping system under irrigated conditions is more remunerative and feasible for the maize growers as compared to the sole *rabi* maize crop.

Conflict of interest

The authors declare no conflicts of interest**.**

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