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Nutrient uptake and economics of maize based intercropping systems under paired row planting

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ABSTRACT

A field experiment was conducted on clay soils of ICAR-NIRCA, Katheru, Rajamahendravaram, during *rabi*, 2024-25 to assess the suitability of these intercrops with maize under paired row planting. The experiment consisted of ten treatments replicated thrice in a Randomised Block Design (RBD), which included maize as main crop and radish, carrot and bhendi as intercrops in different row proportions with maize. The results of the experiment indicated that higher returns and BC ratio can be obtained by intercropping carrot with maize under 2:2 ratio on par with maize + radish (2:2) system and maize + bhendi (2:2) system. The findings conclude that maize + vegetable intercropping under paired row planting is profitable compared to sole maize or sole vegetable cultivation alone.

Keywords: *Intercropping, Maize and Paired row planting*

Maize *(Zea mays* L.) is one of the world's most significant crops and ranks as the third most important cereal crop in India (Chaudhari *et al.,* 2018). Its exceptional genetic yield potential has earned it the prestigious title of "**Queen of Cereals**" globally (Parimaladevi *et al.,* 2019). Intercropping is an agricultural technique of growing two or more crops simultaneously in the same area (Andrews and Kassam, 1976). Vegetables when used as intercrops, not only provide higher monetary returns but also contribute significantly to a balanced diet as they are rich in vitamins, minerals and dietary fibers, in addition to proteins, lipids and carbohydrates. earning them the title "**Protective foods**" (Chaudhari *et al.,* 2018). Carrot *(Daucus carota)* and Radish *(Ricinus sativus)* when intercropped with maize can benetit fronm the shade that maize offers, which keeps the soil wet and lessens weed pressure and can also improve land use efficiency. Bhendi *(Abelmoschus esculentus)* can also be a good companion crop for intercropping with maize as bhendi and maize intercropping produced higher land equivalent ratio (LER) and larger percentage of land savings (Alam *et al.,* 2024). Keeping all these things in view, carrot, radish and bhendi were selected as intercrops and an experiment was designed to find out the influence of different intercropping systems and to find out the profitability of different intercropping systems compared with sole maize.

MATERIAL AND METHODS

The present investigation was carried out at the Research Farm of ICAR-National Institute for Research on Commercial Agriculture (NIRCA) (*formerly CTRI*), Katheru, Rajamahendravaram, which is situated at an altitude of 14 m above MSL, 17.0005^0 N latitude and 81.8040^0 E longitude, comes under the Godavari Agro-climatic zone of Andhra Pradesh. The experiment was conducted during *rabi*, 2024-25, included ten treatments replicated thrice in a randomised block design (RBD). The treatments included T_1: Sole Maize (80/40 cm x 20 cm), T_2 : Sole Radish (40 cm x 10 cm), T_3 : Sole Carrot (40 cm x 10 cm), T_4 : Sole Bhendi (40 cm x 30 cm), T_5 : Maize + Radish (2:1), T_6 : Maize + Carrot (2:1), T_7 : Maize + Bhendi (2:1), T_8 : Maize + Radish (2:2), T_9 : Maize + Carrot (2:2) and T_{10}: Maize + Bhendi (2:2). The soil of the experimental site was clayey in texture, slightly alkaline in reaction, low in electrical conductivity, organic carbon and nitrogen, medium in phosphorus and high in potassium. The intercropping systems were sown on 13th December, 2024. The weekly mean minimum temperature ranged from 16.8 to 23.1^{0}C with an average of 20.4^{0}C. The weekly mean relative humidity ranged from 77.5 to 90.2 per cent with an average of 85.0 per cent and 43.2 to 69.4 per cent with an average of 53.9 per cent at 08: 30 hrs and 14: 30 hrs, respectively. However, no rainfall was recorded during the crop growth period. Maize was sown at a spacing of 80/40 x 20 cm (paired row spacing), carrot and radish at 40 x 10 cm and bhendi at 40 x 30 cm spacing. Recommended doses of 240 kg N, 80 kg P_2O_5 and 80 kg K_2O ha^{-1} (for maize), 60 kg N, 40 kg P_2O_5 and 60 kg K_2O ha^{-1} (for carrot and radish), 120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} (for bhendi) were applied through urea, diammonium phosphate and muriate of potash, respectively. When required, other field operations like plant protection measures were taken. Soil and plant analysis was carried out by following standard procedures as described below:

Soil reaction (pH)

Soil reaction from the experimental plot was determined in 1: 2.5 soil, water suspension using combined glass electrode method (Jackson, 1973).

Electrical conductivity (EC) (dS m^{-1})

The soluble salt content of soil samples was determined in 1: 2.5 soil, water suspension using digital electrical conductivity meter (Jackson, 1973).

Organic Carbon (%)

A known weight (0.5 g) of 0.2 mm sieved soil was treated with a known volume of chromic acid ($K_2Cr_2O_7$ + H_2SO_4). After oxidation of organic carbon, the unreacted potassium dichromate ($K_2Cr_2O_7$) left in the contents was back titrated against standard Ferrous Ammonium Sulphate solution using diphenylamine indicator (Walkley and Black, 1934).

Available Nitrogen (kg ha^{-1})

Available nitrogen content in the soil was determined by Alkaline Potassium Permanganate method (Subbiah and Asija, 1956).

Available Phosphorus (kg ha^{-1})

Available phosphorus in the soil sample was estimated with 0.5 M $NaHCO_3$ of pH 8.5 and the phosphorus in the extract was estimated calorimetrically with ascorbic acid method by using spectrophotometer at 660 nm by Olsen's method (Olsen *et al*., 1954). Per cent P was multiplied with 2.29 and expressed as P_2O_5.

Available Potassium (kg ha^{-1})

Available potassium in the soil was estimated by using Neutral Normal Ammonium Acetate method (Jackson, 1973) and potassium in the extract was determined using flame photometer. Per cent K value was multiplied with 1.21 and presented as K_2O.

PLANT ANALYSIS

N, P and K uptake at harvest (kg ha^{-1})

The plant samples collected at harvest were washed with dilute HCl and then with distilled water. The samples were shade dried initially and then oven-dried at 65 ^{0}C temperature and powdered in Willey mill.

Nitrogen

The nitrogen content in the plant was estimated by micro Kjeldahl distillation method (Piper, 1966) and the results were expressed in percentage.

Phosphorus

Phosphorus in the di-acid extract of plant sample was estimated by Vanadomolybdo phosphoric yellow colour method using spectrophotometer at 420 nm wavelength as described by Tandon (2009) and the results were expressed in percentage.

Potassium

Potassium in the di-acid extract of plant sample was determined using a flame photometer as per the method described by Tandon (2009) and the results were expressed in percentage.

RESULTS AND DISCUSSION

Effects of Intercropping on Yield

Yield of maize and intercrops was higher in sole cropping compared to intercropping systems, which might be due to absence of competition and unrestricted access to resources.

Effects of Intercropping on Plant Nutrient Uptake

Higher nitrogen, phosphorus and potassium uptake by grain (108, 44 and 66 kg ha^{-1}, respectively) and straw (79, 30 and130 kg ha^{-1}, respectively) was recorded from sole maize, whereas lower nitrogen, phosphorus and potassium uptake by grain (79, 34 and 49 kg ha^{-1}, respectively) and straw (51, 21 and 87 kg ha^{-1}, respectively) was recorded from maize + bhendi (2:2) intercropping system. Among the intercrops grown as sole crops, higher nitrogen, phosphorus and potassium uptake by whole plant was recorded from sole bhendi (105, 29 and 94 kg ha^{-1}, respectively).

The higher nutrient uptake in sole maize might be due to the absence of competition, which enabled it to produce more drymatter, leading to a greater nitrogen uptake. However the lower nutrient uptake in maize + bhendi (2:2) intercropping system might be due to lower DMP of maize resulted from competition offered by bhendi and also DMP of bhendi was less due to its reduced population compared to sole cropping, ultimately resulting in less nutrient uptake. Among sole cropping of intercrops, nutrient uptake was higher in sole bhendi, which might be due to its better nutrient uptake and higher drymatter accumulation compared to sole carrot and radish.

Effects of Intercropping on Post Harvest Soil Properties

Soil pH, Electrical Conductivity and Organic carbon were not significantly influenced by intercropping.

EFFECTS OF INTERCROPPING ON AVAILABLE SOIL NUTRIENT STATUS

Available soil Nitrogen (kg ha^{-1})

Significantly higher available soil nitrogen (225 kg ha^{-1}) was registered in maize + bhendi (2:1) intercropping system, but it was on par with other intercropping systems as well as sole maize. Significantly lower available soil nitrogen (151 kg ha^{-1}) was registered in sole radish, which in turn was comparable with sole carrot (161 kg ha^{-1}) and sole bhendi (183 kg ha^{-1}).

The higher availability in maize + bhendi (2:2) system might be due to the differences in rooting depth of both the crops (shallow rooted maize and deep rooted bhendi). When two crops of different rooting depth were intercropped, they draw nutrients and moisture from different layers of the soil profile and it results in efficient utilisation of nutrients (Nasar *et al.* 2024). Maize intercropping enhanced soil available nitrogen might be due to the enhanced enzymatic activities and microbial populations (Nasar *et al.* 2024). Regardless of the intercrop and row ratio, intercropping significantly enhanced available soil nitrogen and decreased both available phosphorus and potassium (Padhi and Panigrahi, 2006).

Available soil phosphorus and Potassium(kg ha^{-1})

Significantly, higher available soil phosphorus and potassium (39 kg ha^{-1} and 476 kg ha^{-1}) were registered in sole radish, which was on par with sole bhendi (38 kg ha^{-1} and 453 kg ha^{-1}) and sole carrot (33 kg ha^{-1} and 468 kg ha^{-1}). Significantly lower available soil phosphorus and potassium (22 kg ha^{-1} and 366 kg ha^{-1}) were observed in sole maize, but it was on par with maize + radish (2:1 and 2:2) intercropping systems (26 kg ha^{-1} each).

The higher available soil phosphorus and potassium in sole radish might be attributed to its early harvest, resulting in reduced nutrient uptake duration compared to other crops. This might had left more residual nutrients in the soil. Conversely, the lower P and K content in sole maize could be due to more efficient uptake by maize, especially in the absence of competition from intercrops. Similarly, in intercropping systems, the combined uptake by both the main crop and intercrops might have led to greater depletion of available phosphorus and potassium, resulting in intermediate values. The results are in conformity with those of Nasar *et al.* 2024.

Influence of intercropping on Economics of the System

Significantly higher gross returns (₹306937 ha^{-1}), net returns (₹237017 ha^{-1}) and BC ratio (3.4) were recorded from maize + carrot (2:2) system, which was on par with maize + radish (2:)system (₹ 287257 ha^{-1}, ₹.219237 ha^{-1} and 3.2, respectively) and maize + bhendi (2:2) system (₹ 289993 ha^{-1}, ₹219073 ha^{-1} and 3.1, respectively). Significantly lower gross returns (₹174653 ha^{-1}), net returns (₹113933 ha^{-1}) and BC ratio (1.9) were recorded under sole maize.

The higher yields in 2:2 ratio intercropping systems might be attributed to the additional produce from two rows of intercrops. In addition, carrot and bhendi fetched better market prices, boosting overall returns. Radish, though sold for lower price, due to higher yields, contributed to higher returns. Sole maize, despite its superior yield, had lower returns due to the lack of additional income from intercrop component.

Table 1. Effect of intercropping systems on yield of maize and intercrops

Treatments	Grain Yield (Kg ha-1)	Stover Yield (Kg ha-1)	Tuber yield (kg ha^{-1})	Fruit yield (kg ha^{-1})
T_1 : Sole maize (80/40 x 20 cm)	7914	10005	-	-
T_2 : Sole Radish (40 x 10 cm)	-	-	15225	-
T_3 : Sole Carrot (40 x 10 cm)	-	-	12793	-
T_4 : Sole Bhendi (40 x 30 cm)	-	-	-	10427
T_5 : Maize + Radish (2:1)	6957	8799	4676	-
T_6 : Maize + Carrot (2:1)	6973	8833	4248	-
T_7 : Maize + Bhendi (2:1)	6275	7211	-	3080
T_8 : Maize + Radish (2:2)	6591	7683	8936	-
T_9 : Maize + Carrot (2:2)	6624	7800	8061	-
T_{10}: Maize + Bhendi (2:2)	6065	7108	-	6256
SEm$\pm$	489.9	841.8	-	-
CD (P = 0.05)	1067	1834	-	-
CV (%)	8.9	12.5	-	-

Table 2. Effect of intercropping on plant nutrient uptake (Data not analysed statisticaly)

Treatments	Maize N uptake (kg ha-1)		N uptake by intercrop (kg ha-1)*	Maize P uptake (kg ha-1)		P uptake by intercrop (kg ha-1)*	Maize K uptake (kg ha-1)		K uptake by intercrop (kg ha-1)*
	Grain	Stover		Grain	Stover		Grain	Stover	
T_1 : Sole Maize	108	79	-	44	30	-	66	130	-
T_2 : Sole Radish	-	-	85	-	-	16	-	-	65
T_3 : Sole Carrot	-	-	72	-	-	21	-	-	71
T_4 : Sole Bhendi	-	-	105	-	-	29	-	-	94
T_5 : Maize + Radish (2:1)	95	70	28	39	26	5	57	114	20
T_6 : Maize + Carrot (2:1)	94	68	24	38	26	7	56	112	22
T_7 : Maize + Bhendi (2:1)	85	55	34	36	21	10	50	89	30
T_8 : Maize + Radish (2:2)	87	57	53	37	23	10	54	98	38
T_9 : Maize + Carrot (2:2)	88	58	44	37	22	12	53	97	42
T_{10}: Maize + Bhendi (2:2)	79	51	62	34	21	19	49	87	58

*Whole pant uptake by vegetables grown as sole crops and as intercrops

Table 3. Effect of intercropping on post harvest soil properties

Treatments	pH	EC (dS m^{-1})	Organic Carbon (%)
T_1 : Sole Maize (80/40 x 20 cm)	7.53	0.32	0.5
T_2 : Sole Radish (40x 10 cm)	7.52	0.3	0.45
T_3 : Sole Carrot (40x 10 cm)	7.42	0.31	0.51
T_4 : Sole Bhendi (40x 30 cm)	7.54	0.32	0.45
T_5 : Maize + Radish (2:1)	7.42	0.31	0.48
T_6 : Maize + Carrot (2:1)	7.43	0.36	0.45
T_7 : Maize + Bhendi (2:1)	7.44	0.32	0.46
T_8 : Maize + Radish (2:2)	7.38	0.32	0.45
T_9 : Maize + Carrot (2:2)	7.5	0.33	0.48
T_{10}: Maize + Bhendi (2:2)	7.4	0.32	0.46
SEm$\pm$	0.18	0.01	0.02
CD (P = 0.05)	NS	NS	NS
CV (%)	3	602	5.8
Initial	7.69	0.31	0.52

Table 4. Effect of intercropping on available soil nutrient status

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1 : Sole Maize (80/40 x 20 cm)	214	22	366
T_2 : Sole Radish (40x 10 cm)	151	39	476
T_3 : Sole Carrot (40x 10 cm)	161	33	468
T_4 : Sole Bhendi (40x 30 cm)	183	38	453
T_5 : Maize + Radish (2:1)	211	26	376
T_6 : Maize + Carrot (2:1)	213	24	372
T_7 : Maize + Bhendi (2:1)	225	28	396
T_8 : Maize + Radish (2:2)	205	26	377
T_9 : Maize + Carrot (2:2)	211	24	377
T_{10}: Maize + Bhendi (2:2)	210	23	374
SEm$\pm$	16.3	3.1	32.3
CD (P = 0.05)	34	6	68
CV (%)	10.1	13	9.8
Initial	212	22	480

Table 5. Economics of maize + vegetable intercropping systems

Treatments	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit – cost ratio
T_1 : Sole Maize (80/40 x 20 cm)	174653	113933	1.88
T_2 : Sole Radish (40x 10 cm)	243600	178540	2.74
T_3 : Sole Carrot (40x 10 cm)	255860	187340	2.73
T_4 : Sole Bhendi (40x 30 cm)	258633	181013	2.33
T_5 : Maize + Radish (2:1)	228320	161750	2.43
T_6 : Maize + Carrot (2:1)	238979	172059	2.57
T_7 : Maize + Bhendi (2:1)	214928	146278	2.13
T_8 : Maize + Radish (2:2)	287257	219237	3.22
T_9 : Maize + Carrot (2:2)	306937	237017	3.39
T_{10}: Maize + Bhendi (2:2)	289993	219073	3.09
SEm$\pm$	20747.8	20747.8	0.3
CD (P = 0.05)	43591	43591	0.63
CV (%)	10.2	14	13.9

CONCLUSION

From the study, it can be concluded that plant nutrient uptake was higher from sole maize compared to intercropping systems. All the intercropping systems resulted in nearly similar amounts of residual nitrogen in soil, whereas significantly higher soil P and K was found in sole radish on par with sole carrot and sole radish. However, soil physico-chemical properties were not significantly influenced by intercropping. Maize when intercropped with vegetables produced higher net returns and BC ratio compared to sole maize grown under paired row planting by making use of available space in between two paired rows of maize. Therefore, it is suggested to go for intercropping of maize with vegetables like carrot, radish and bhendi for enhancing the profitability of the system.

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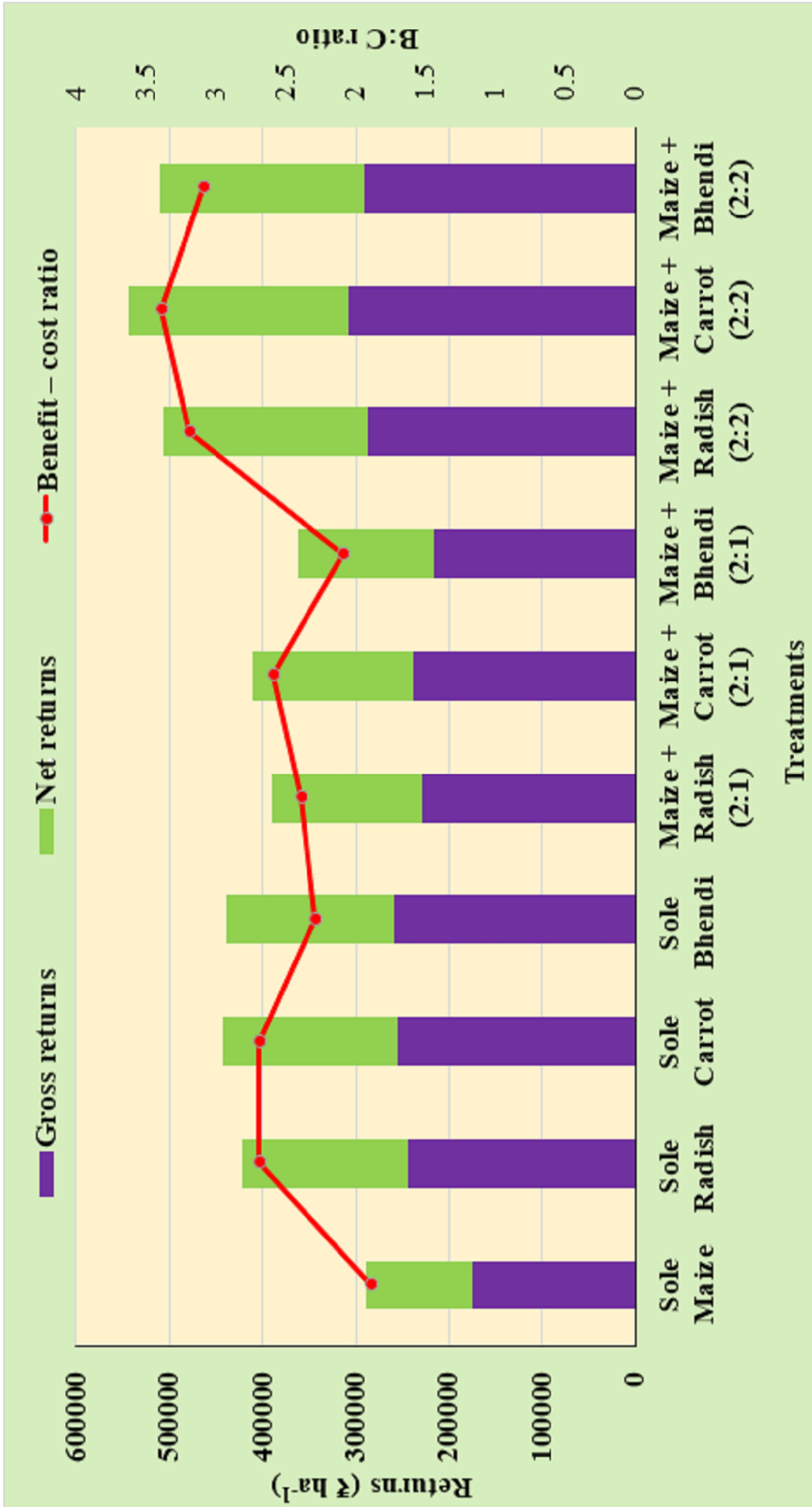

Fig 1. Economics of maize + vegetable intercropping systems

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