Journal of AgriSearch, 12 (2): 93-99
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v12i02.15240

Effects of Fertility Levels, Planting Density and Sowing Methods on Productivity and Soil Fertility Status in Rabi Maize + Toria Intercropping

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ABSTRACT

The experiment was conducted during the rabi season of 2017-18 and 2018-19 at research farm of AAU, Jorhat, Assam to identify the most suitable fertility levels, row spacing and methods of sowing on growth, productivity and fertility status in quality protein maize + toria intercropping. The experiment was laid out in factorial RBD with treatment combination of three fertility levels (60:40:40 kg NPK/ha, 90:60:60 kg NPK/ha and 120:80:80 kg NPK/ha), three paired row spacing, 55cm x 25cm, 65cm x25cm,75cm x 25 cm with two methods of sowing (Normal sowing and paired row sowing). Results revealed that the pooled (2 years) yield attributes and yields were recorded with higher levels of fertility in maize and toria crop. Maximum maize equivalent yield was also recorded with higher fertility levels. Similarly paired row intercropping of 65 cm x 25cm recorded significantly highest yield attributing characters, grain of quality protein maize and toria along with significantly higher maize equivalent yield. However in MEY, the intermediate paired row spacing of 65 cm x 25 cm remained statistically at par with the closure spacing of 55 cm x 25 cm. Paired row planting of maize recorded significantly higher maize equivalent yield than that of the normal row planting of the study. Soil fertility status of NPK was significantly higher with highest fertility levels after two cropping cycles. The study suggests that successful intercropping of rabi maize with toria in paired row spacing of 65 cm x 25 cm with 2:2 row ratio along with highest fertility levels ie., 120:80:80 kg NPK/ha is recommended for the Assam.

ARTICLE INFO

Received on	:	08/05/2025
Accepted on	:	21/06/2025
Published online	:	30/06/2025

Keywords: Quality protein maize, Fertility levels, Planting density, Yield, Soil fertility

INTRODUCTION

Maize (Zea mays L.) is one of the most valuable cereal crops used in the human nutrition in various parts of the globe and it is a vital feed source for livestock. In India maize is the third most important food crop after rice and wheat grown an area of 8.67 Mha with the production and productivity of 21.75 Mt and 2566 kg/ha, respectively (GoI, 2014). Maize contributes nearly nine per cent (9%) to the national food basket and more than Rs.100 billion to the agricultural GDP at current prices apart from generating employment to over 100-million-man days (Tripathi et al., 2016). Several million people, particularly in the developing countries, derive their protein and calorie requirements from maize (Mboya et al., 2011). In spite of several important nutritious use maize has a drawback of deficiency in two essential amino acids viz., lysine and tryptophan which reduces the biological value of maize protein. Quality Protein Maize (QPM) has been developed by incorporating opaque 2 gene to overcome this problem as QPM contains twice the quantity of essential amino acids. Thus, QPM cultivation provides an opportunity to the farmers for producing nutritionally superior maize grains where maize serves as a staple food and main source of proteins in many developing countries.

Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops. One of the novel and potential opportunities to meet this demand is by adopting intercropping of different compatible crops scientifically which in turn increase the arable area under different crops and also have certain in-built advantage over pure cropping (Velayutham and Somasundaram, 2000). Intercropping, growing or production of two or more crops simultaneously on the same field, is a simple but inexpensive strategy of crop intensification is in both time and space dimensions and has been recognized in India long back as a potentially benefited technology for increase crop production (Awal et al., 2006) which ensure substantial yield advantages as compared to sole cropping (Rao and Singh, 1990) and the farmers are practicing this system in some form or the other since many centuries. Maize is an exhaustive crop which requires all types of macro and micro nutrients for better growth and yield potential and requires continuous and assured nutrient supply throughout the growing period from germination to

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grain filling stage. Hence, proper nutrient management with adequate amount of nitrogen, phosphorus and potassium fertilization is considered to be one of the most important prerequisites for increasing productivity of maize. Row spacing response interacts with maize hybrid and plant population (Farnham, 2001). Altering row spacing influences interception of solar radiation and weed control (Teasdale, 1995), as well as capital investment requirements (Karlen and Camp, 1985). Recent row spacing interest for increasing maize grain yield and resource efficiency has been focused on skip-row systems for water limiting environments (Lyon et al., 2009) and twin/paired-row production systems as alternative row configuration for high yield environments (Great Plains, 2011) which split the plant population of one single row into two staggered rows of narrow spacing (Great Plains, 2011) resulting more equidistant plant distribution than with conventional wider row spacing. Improved plant distribution reduces intra-row competition for solar radiation, water, and nutrients and thereby promotes root growth by improving water and nutrient uptake (Karlen and Camp, 1985).

Paired row technique is suitable for intercropping and has been developed without reduction in plant population for effective and efficient utilization of resources by component crops, there by harness maximum yield advantage from an intercropping system (Waghmore et al., 1982). In paired row planting, the two paired rows of the principal crops were sown close together and the large space is left before the next paired rows, the space can be intercropped which prevents main crop shading and therefore improves companion crop development. Considering all the points which may be helpful in ensuring rational use of resources and increasing the productivity for sustainable agriculture system, an investigation was conducted to find out a proper nutrient level with planting density in paired row during the rabi season for quality protein maize and toria intercropping system.

MATERIALS AND METHODS

The experiment was conducted during two consecutive years of 2017-18 and 2018-19 at the experimental farm of Assam Agricultural University at 26°45N latitude and 94°12E longitude at an altitude of 87 meters above the mean sea level (MSL) and falls under Upper Brahmaputra Valley Zone of Assam. In general, maximum temperature rises up to 34-37°C during summer and minimum comes down to 8-10°C during winter. The total rainfall received during 2017-18 was 122.2 mm against 112.5 mm during 2018-19. During both the years of experimentation meteorological parameters were more or less same and the crops were normal. The soils of the experimental site were sandy loam in texture, acidic in reaction (pH-5.34) medium in organic carbon (0.63), available nitrogen (283.76), available potassium (180.42), and high in available phosphorus (28.32) respectively.

The experimental site was laid out in factorial randomized block design with three replications and treatment combinations of three nutrient levels with three row spacings in paired and normal rows (Fig. 1-3) with 60:40:40 kg NPK/ha, 90:60:60 kg NPK/ha and 120:80:80 kg NPK/ha. Maize was intercropped with toria in three paired row spacing 55cm x 25cm, 65cm x 25cm, 75cm x 25 cm respectively with two methods of sowing (Normal sowing and Paired row sowing). Maize variety (Vivek QPM-9) and toria variety (JT-90-1) were selected for maize + toria intercropping. Recommended seed rates of maize (25 kg ha-1) and toria (8 kg ha-1) were sown for both the years. Sowing was done in lines at different spacing according to the treatment manually for both maize and toria.

RESULTS AND DISCUSSION

The survey was conducted at fortnightly interval in nine different blocks of Purnea district, namely Kasba, Jalalgarh, Dhamdaha, B. Kothi, Bhawanipur, Dagrua, Amour, Purnea East and Rupauli during kharif and rabi of 2019-2021. The larval load and per cent infestation of fall armyworm were recorded during the roving survey (Fig. 1).

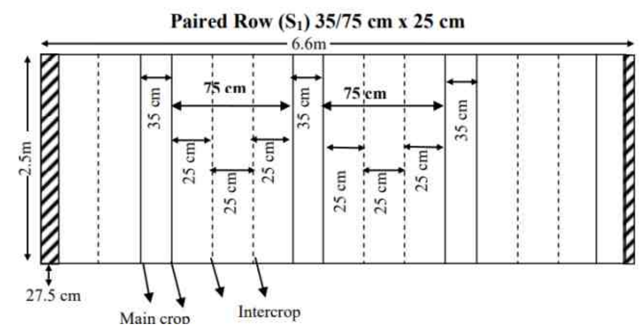

Fig.1: Row arrangements of intercrops

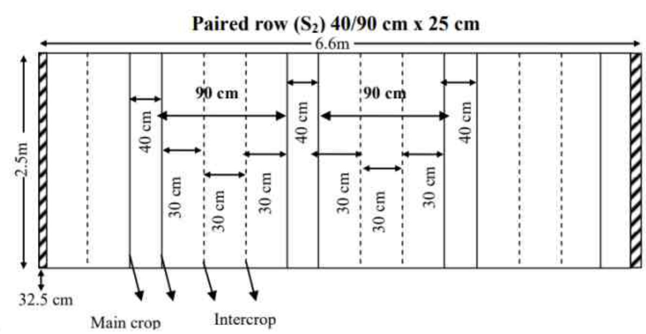

Fig.2: Row arrangements of intercrops

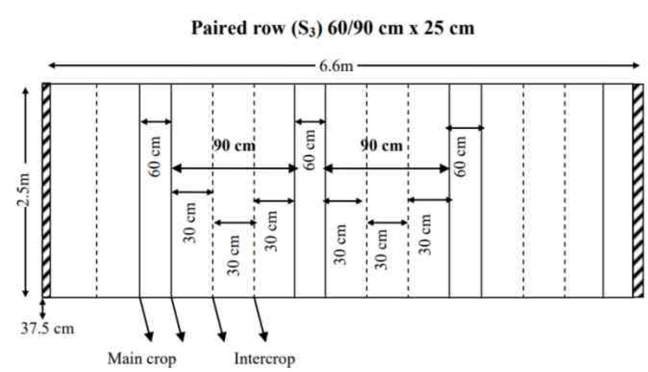

Fig. 3: Row arrangements of intercrops

Recommended doses of NPK were applied in the form of urea, single super phosphate and muriate of potash, respectively and doses of fertilizers were applied in the plots as per the treatments. Full doses of phosphatic and potassic fertilizers and half dose of nitrogenous fertilizer were applied as uniformly as possible before sowing. The rest half of the nitrogenous fertilizer was applied as top dressing during the time of earthing up. Whenever necessary, gap filling and thinning operations were carried out within seven days after emergence to maintain the optimum plant population by dibbling the seeds for both maize as well as toria. Maize was sown on 24th November and 20th November and harvested on 10th March and 15th March in the year 2017-18 and 2018-19 respectively. Irrigations were adjusted as per the rainfall received during the season. Irrigation was given to the crop in the critical stages like grand growth period, teaselling and grain setting stages of maize crop during both the years of experimentation. For the management of soil-borne pathogens, neem cake was added uniformly in all the plots @150 kg ha−1 during last ploughing and mixed with the soil during both the years of experimentation. Toria crop was infested by mustard saw fly during 2017–18 and was controlled by spraying of "rogor" @ 0.2 per cent. There was no any incidence of insect pests and diseases during the 2nd year of experimentation in toria as well as maize during both the years. Representative plant samples of grain and seed as well as stover were collected from each plot at the time of harvest of each crop. Observations on yield attributes at maturity of the crops, from 5 randomly selected plants were recorded. Harvesting of maize and toria were done during the bright sunny days on net plot area basis. Harvested cobs were dried in threshing floor for 10-15 day to reduce the moisture up to optimum level. The harvested dried cobs were weighed; grains were separated from cob manually and put into separate bags with proper labels. After completion of picking, the plants were allowed to stand in the field for a week. Finally, the stalks were cut from ground level from the net plot and weighed after sun drying for stover yield estimation. The yield of crops was converted to Maize grain equivalent yield (MEY) on the basis of the existing market prices of the crops. Soil samples were collected from 0 to 15 cm depth before initiation of the study and after two cropping cycles. The organic carbon, nitrogen, phosphorus and potassium were analyzed as per standard procedure. Economics were worked out as per the prevailing market price of inputs and outputs. Two year mean data was analysed through statistical methods of factorial design. The significance of different sources of variations was tested by error mean square of Fisher Snedecor's 'F' test at 5% probability level (p = 0.05). In the summary tables of the results, the standard error mean (SEm (±)) and critical difference (CD) were provided to compare the means.

RESULTS AND DISCUSSION

Yield Attributes of Maize

Application of fertility levels resulted in significant increase of yield attributes of maize crop (cob length, cob girth and 1000 grain weight) except the number of cobs per plant during the study. Significant increase in all the yield attributing characters with the corresponding increase in the levels of NPK up to 120:80:80 kg/ha (Table 1).

Table 1: Effect of different levels of fertilizer, spacing and method of sowing on yield attributes of quality protein maize (pooled 2 years)

Treatment	Cobs /plant (nos.)	Cob length (cm)	Cob girth (cm)	Test weight (g)
Levels of fertilizer(N-P_2O_5-K_2O kg ha^{-1})				
F_1: 60-40-40	1.02	16.34	11.61	223.41
F_2: 90-60-60	1.1	18.54	12.48	232.97
F_3: 120-80-80	1.16	19.705	13.79	250.20
S.Em. (±)	0.03	0.21	0.23	3.28
C.D. (P=0.05)	NS	0.60	0.71	9.86
Spacing				
S_1: 55 cm x 25 cm	1.05	18.47	12.82	234.76
S_2: 65 cm x 25 cm	1.10	19.66	13.485	246.75
S_3: 75 cm x 25 cm	1.16	16.46	11.59	225.07
S.Em. (±)	0,03	0.21	0.23	3.28
C.D. (P=0.05)	NS	0.61	0.68	9.86
Method of sowing				

Treatment	Cobs /plant (nos.)	Cob length (cm)	Cob girth (cm)	Test weight (g)
Levels of fertilizer(N-P_2O_5-K_2O kg ha^{-1})				
Method of sowing				
P_0: Normal row	1.05	19.36	13.455	241.19
P_1: Paired row	1.05	17.03	11.805	229.86
S.Em. (±)	0,02	0.20	0.19	2.72
C.D. (P=0.05)	NS	0.59	0.56	8,14

However, the test weight recorded under 60:40:40 and 90:60:60 kg/ha NPK remained at par and with each other. The increase in grain weight may be due to better translocation and partitioning of photosynthates from source to sink *i.e.* seeds (Ahmed *et al*., 2010). Increase in yield attributes may have been brought about by increase in amount of growth substances and naturally occurring phytohormones probably auxins, with increased nutrient supply. Sharma and Gupta (2006) also reported increased yield attributes of pearlmillet with increase in nitrogen and phosphorus doses in intercropping. All the yield attributing parameters *viz*., number of cobs/ plant, cob length, cob girth and test weight of 1000-grains of quality protein maize intercropped with *toria* were found to increase with increase in paired row spacing up to 65 cm x 25 cm and thereafter a decrease in the widest row spacing of 75 cm x 25 cm. The lower values of yield attributes under wider row spacing during both the seasons might be due to competition for growth resources within the row. The results are in conformity with those of Kanwar and Srivastava (2000). Higher values of all these parameters were recorded under normal row planting of sole maize as compared to paired row intercropping of maize + *toria*. The possible reason for lower number of cobs $plant^{-1}$, cob length, cob girth and 1000 grain weight of QPM under paired row intercropping may be due to higher competition with associate crop *toria* for space, soil moisture and nutrient during entire crop season. (Aziz *et al*., 2012; Sonam *et al*., 2014)

Yield Attributes of Intercrop

All the three yield attributing parameters of intercrop *toria* increased with the increasing levels of fertilizer from 60:40:40 to 120:80:80 kg NPK/ha. Significant effect of paired row spacing of QPM + *toria* intercropping was noticed on all the yield attributing characters of *toria* which significantly increased with increase in dimension of paired row spacing from 55 cm x 25 cm to 65 cm x 25 cm and thereafter a decrease with further increase in spacing to 75 cm x 25 cm. The variations in yield attributes of intercrop *toria* were due to competition among the crop plants and dominating effect of main crop maize (fig. 4). These results are similar to that of Kebebew *et al.* (2014) and Aziz *et al.* (2012) who also reported that different planting arrangements on maize had significant effect on yield attributes of intercrop soybean.

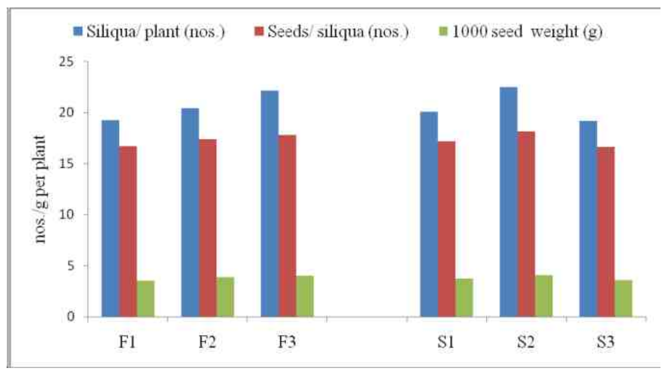

Fig.1: Yield attributes of toria under different levels of fertilizer, spacing under paired row intercropping

Grain Yield

Pooled (2 years) yield of maize and toria were presented in the table 2. Maize and toria seed yield were significantly increased with increasing levels of fertilizers doses i.e., 60:40:40, 90:60:60 and 120:80:80 NPK kg/ha. Maximum seed yield of maize and toria were recorded 51.42 q/ha and 4.67 q/ha with the application of 120:80:80 kg NPK during the year of study and minimum yield was recorded 42.95 q/ha and 2.75 q/ha with lower doses of fertilizer levels (60:40:40 kg NPK/ha). Percentage increase in maize and toria yield were 11.65 %, 8.1 % and 70 %, 31.1 % higher with the application of 120:80:80 and 90:60:60 kg NPK/ha, respectively over 60:40:40 kg NPK/ha

Table 2: Effect of different levels of fertilizer, spacing and method of sowing on yield maize equivalent yield and economics (pooled 2 years)

Treatment	Maize grain yield (q/ha)	Toria seed yield (q/ha)	MEY (q/ha)	Net return (Rs/ha)	B:C ratio	PE (kg/ha/day)	EE (Rs/ha/day)
Levels of fertilizer(N-P_2O_5-K_2O kg ha^{-1})							
F_1: 60-40-40	42.95	2.75	46.00	52256.27	2.85	20.70	235.02
F_2: 90-60-60	47.95	3.60	51.26	58831.06	2.90	23.39	268.23
$F_{3:}$ 120-80-80	51.42	4.67	55.83	64194.22	2.91	25.92	298.11
S.Em. (±)	0.60	0.11	0.62	-	-	-	-
C.D. (P=0.05)	1.72	0.31	1.81	-	-	-	-
Spacing							
S_1: 55 cm x 25 cm	47.87	3.505	52.065	58834.39	2.81	23.67	267.43
S_2: 65 cm x 25 cm	50.30	4.565	53.785	63246.53	3.05	24.56	288.80
S_3: 75 cm x 25 cm	44.15	2.945	47.25	53200.64	2.80	21.77	245.16
S.Em. (±)	0.60	0.11	0.62	-	-	-	-
C.D. (P=0.05)	1.72	0.31	1.81	-	-	-	-
Method of sowing							
P_0: Normal row	49.22	-	49.22	55931.92	2.85	22.58	256.57
P_1: Paired row	45.66	-	52.845	60922.46	2.93	24.02	276.92
S.Em. (±)	0.49	-	0.51	-	-	-	-
C.D. (P=0.05)	1.43	-	1.44	-	-	-	-

MEY: Maize equivalent yield

Among the spacing, maximum maize grain yield was recorded 50.30 q/ha with 65 cm x 25 cm followed by 55 cm x 25 cm (47.87 q/ha) and 75 cm x 25 cm (44.15 q/ha) during the experimentation. Normal row of maize sowing was significantly recorded higher maize grain yield as compared to paired row during both the year of experimentation. Maize grain yield was recorded 49.22 q/ha and 45.66 q/ha with normal row and paired row sowing methods during the year of study. Maize yield increased due to increasing levels of fertilizer doses could be attributed to increased accumulation and partitioning of dry matter with the increasing fertility levels. Seed yield of toria was significantly influenced by different spacing. Maximum seed yield of toria was obtained 4.56 q/ha with spacing of 65 cm x 25 cm followed by 3.50 q/ha with 55 cm x 25 cm and minimum 2.94 q/ha in a spacing of 75cm x 25 cm. Beremjungla and Gohain (2016) also reported that application of 100 per cent recommended dose of fertilizer to maize and intercrop groundnut increased the grain yield to both the crops during both the years of study. Temesgen et al. (2017) reported similar findings in maize and common bean intercropping.

Maize Equivalent Yield

The maize equivalent yield (MEY) of maize, toria intercropping significantly increases with increasing fertilizer level during study. Maximum MEY was recorded 55.83 q/ha with the fertility levels 120:80:80 kg NPK/ha and followed by 51.26 q/ha with the application of 90:60:60 kg NPK/ha and minimum MEY produced 46.00 q/ha with lowest fertility levels i.e, 60:40:40 kg NPK/ha. This might be due to that high dose of fertilizer produces maximum yield of maize and toria crop. Kheroar and Patra (2014) also obtained higher maize grain equivalent yield in all the cases of intercropping of maize with greengram, blackgram, soybean, groundnut and redgram than sole maize. Similar findings were reported by Kumar and Nandan (2007). There was an increasing trend of MEY in maize + toria system up to the paired row spacing of 75 cm x 25 cm. However, the intermediate paired row spacing of

65 cm x 25 cm remained statistically at par with the closure spacing of 55 cm x 25 cm. Significant increase in maize equivalent yield because of increased levels of fertility to main and intercrop appears to be the result of higher productivity of both the crops with increasing levels of fertilizers.

Method of sowing had significant effect on MEY during the period of study. Paired row planting of maize recorded significantly higher equivalent yield of 52.84 q/ha than that of the normal row planting (49.22 q/ha) during the study. The higher equivalent yield of maize showed higher biomass production and efficient use of available growth resources under intercropping than sole cropping. The different behavior in crop equivalent yield was also on account of productivity of crops in intercropping systems and their relative market prices. These results also corroborate with the findings of Kumar et al. (2017), who higher equivalent yield in paired row intercropping of maize with mungbean.

Soil Fertility

After two cropping cycles, maximum available N, P and K were significantly recorded 253.96 kg/ha with application of higher doses of fertility level (120:80:80 kg NPK/ha) and lowest value of available N, P and K were noted in plot treated with 60:40:40 kg NPK/ha (Table 3). The reason for higher values in fertility levels might be due to the fact that at higher levels availability of the nutrients are increased to the crop in an adequate amount which stays in soil in substantial amount after fulfillment of the crop need that results improvement in soil fertility. This has been confirmed by the research carried on by Manea et al. (2015). Available phosphorus was reduced in all the plots despite of having recommended P dose to the entire plot which might be due to phosphorus fixation in soils, ultimately resulting in reduced availability of phosphorus.

Table 3: Soil fertility as influenced by fertilizer levels, spacing and method of sowing after two cropping cycles.

Treatments	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Levels of fertilizer(NPK kg/ha)			
60-40-40	216.63	24.89	169.25
90-60-60	235.66	25.45	169.98
120-80-80	253.96	27.68	184.53
S.Em. (±)	4.28	0.46	0.97
C.D. (P=0.05)	12.30	1.32	2.78
Spacing			
55 cm x 25 cm	234.13	25.14	174.67
Levels of fertilizer(NPK kg/ha)			
65 cm x 25 cm	246.22	26.78	175.62
75 cm x 25 cm	225.89	26.10	173.47
S.Em. (±)	4.28	0.46	0.97
C.D. (P=0.05)	12.30	NS	NS
Method of sowing			
Normal row	230.43	25.98	173.46
P_1: Paired row	240.40	26.02	175.72
S.Em. (±)	3.49	0.37	0.79
C.D. (P=0.05)	NS	NS	NS
Initial	283.76	28.32	180.42

Availability of NPK were found to increase with the increase in dimension of paired row spacing from 55 cm x 25 cm to 65 cm x 25 cm and thereafter a decrease with further increase in spacing to 75 cm x 25 cm .The increase in available N in soil under spacing of 65 cm x 25 cm treatment might be due to higher biomass production under closure planting density which resulted in increased uptake under the above situation. Method of sowing in maize + toria intercropping did not have any influence on the available NPK status of soil at harvest of maize crop. However, comparatively higher values were recorded in the paired row treatments than that in normal row planting.

Economics

Economics worked out on the basis of input cost and selling price of seed as per the prevailing market price. Results revealed that the maximum net returns (Rs.64194.22/ha) and benefit cost ratio (2.91) were recorded with the application of 120:80:80 kg NPK per ha among the different fertility levels (Table 2). Amongst the different spacing, 65 cm x 25 cm spacing recorded highest net return (Rs.63246.53/ha) and B:C ratio(3.05) and which was followed by row spacing of 55cm x 25cm. In methods of sowing, maximum net return and benefit cost ratio were recorded Rs.60922.46 /ha and 2.93 respectively in paired row methods of sowing. The trend was observed in economic efficiency. The higher economic returns were obviously due to higher seed yield due to higher fertility levels along with wide spacing an this could be attributed to higher yield advantage under intercropping of maize with toria. In agreement with these results, higher net monetary return was also reported by Sonam et al. (2014).

CONCLUSION

Based on field experimentation it may be concluded that quality protein maize can be successfully grown with toria as intercrop in paired row spacing of 65 cm x 25 cm with 2:2 row ratio along with application of 120:80:80 kg NPK/ha.

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Citation:

Sarma M, Kurmi K and Kumar M.2025. Effects of fertility levels, planting density and sowing methods on productivity and soil fertility status in rabi maize + toria intercropping. Journal of AgriSearch 12(2): 93-99.