INTERCROPPING OF RABI MAIZE AND CHICKPEAS AND THE EFFECTS OF ITS RESIDUAL MANAGEMENT ON SUCCEEDING SUMMER GREENGRAM

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Abstract

The experimental field featured a flat, gently sloping surface that was well-drained and composed of loamy sand. The soil in the experimental field was somewhat alkaline in response and had low levels of organic carbon and accessible nitrogen between 0 and 15 centimetres deep. Each treatment (T1, T2, T3, T4, T5, and T6) was tested with four replicates, and the treatments ranged from growing only maize, only chickpea, growing both at a 1:1 ratio in an adding series, growing both at a 1:1 ratio in a replacing series, growing both at a 2:1 ratio in a paired row, and finally growing both at a 2:2 ratio in a paired row. There are six types of intercropping systems. T1 is a single row of maize, T2 is a single row of chickpeas, T3 is an additive series of maize and chickpeas, T4 is a replacement series of maize and chickpeas, T5 is a paired row of maize and chickpeas, and T6 is a paired row of maize and chickpeas and two crop residue management. Treatments R0 (no crop residue) and R1 (some crop residue).

Keywords: *Intercropping, Rabi Maize, Chickpeas, Residual Management, Green gram.*

1. Introduction

Maize is extensively farmed across the world’s 170 nations with larger range of soil, climate, biodiversity and management approaches that generates 1147.7 MT worldwide grain output from an area of 193.7 million ha with average productivity of 5.75 tones/ha. The United States of America (USA) is the world leader in maize production, contributing over 40% of worldwide output. In comparison to other nations, the United States of America (USA) has twice the worldwide average productivity (4.92 t/ha) whereas India only has an average productivity of 2.80 t/ha. In India, almost every state produces maize year-round for a wide variety of uses, from grain and fodder to green cobs, sweet corn, baby corn, and popcorn in the country's peri-urban areas. With an average yield of roughly 2.80 tones/ha, India's 9.60 million hectares (ha) of maize fields produce 27.15 million tonnes. More than 80% of India's maize harvest comes from only a few of states: Karnataka (12.36%), Maharashtra (12.33%), Madhya Pradesh (12.32%), Tamil Nadu (9.20%), Telangana (8.94%), Bihar (8.44%), Andhra Pradesh (8.02%), Rajasthan (5.71%), and Uttar Pradesh (5.14%). There are around 0.44 million hectares devoted to maize cultivation in Gujarat, yielding approximately 0.68 million metric tonnes (Anon., 2018). Dahod, Panchmahal, Anand, Vadodara, and Narmada, all located in central Gujarat, are the state's most important maize-producing districts.[1-2]

The basic goal of intercropping is to maximise overall production per unit area and time while also ensuring that land resources, agricultural inputs, such as manpower, and other costs are distributed fairly and used efficiently. While intercropping does provide some protection from biotic and abiotic stresses, its primary purpose is to maximise the efficiency with which existing resources are used.[3]

Cereal and legume intercropping systems are common in India. Legumes offer an essential channel to reduce the limits associated to nitrogen limitations in the soil and boost crop output. They may swiftly cover the soil surface, lowering the risk of erosion, while also preventing the growth of weeds, reducing the spread of pests and diseases, balancing out the requirement for work, and increasing the productivity of the land. Maximum amounts of higher quality organic matter inputs are created when pulses are intercropped with cereal crops, resulting in larger productivity gains compared to continuous cultivation of maize as a solitary crop. Improvements in physical, chemical, and biological soil characteristics are largely responsible for the positive effects that cereal-legume intercropping systems have on productivity, profitability, and soil health. In view of the changing climate, this method has enormous potential to increase food production on marginal and degraded land in poor nations.[4-5]

Wider row spacing is typical for maize crops, and the empty space between rows may be put to good use. Although intercropping has been used for thousands of years, its maximum yield benefits have only recently come to the attention of the global agricultural community. The capacity of the component crops to utilise growth resources differently means that, when these crops are grown together, they complement each other and make overall better use of resources compared to when they are separately farmed, which is one of the key reasons to gain greater yield in intercropping. In an intercropping system, pulses not only provide nitrogen to the neighbouring crops, but also boost humus levels when the crop residue decomposes.[6-7]

2. Literature review

Baishya L.K. and D.J. Rajkhowa. (2020) In 2018, scientists from Odisha's Centurion University of Technology and Management conducted experiments on the impacts of a summer maize-legume intercropping system on yield characteristics, yield, competitive abilities, and economics in the region's sub-humid and subtropical environment. The findings showed that intercropped legumes increased maize yield and its component parts. They found no statistically significant differences in the augmentation of 100 grain weight of maize among intercropping systems, but they did find that solo maize resulted in considerably greater grain weight per cob (56.21 g) and grain weight per plant (73.07 g) than the other treatments.[8]

Islam Mokidul and T. Samajdar. (2019) During the rabi seasons of 2017–18 through 2019–20 at the Anand Agricultural University in Anand, an experiment was carried out to determine the impact of maize–chickpea intercropping systems and integrated nitrogen management. Plant height of maize and chickpea, evaluated on a regular basis at 30, 60, and harvest to determine the effects of intercropping systems, showed no statistically significant effect on treatments at any developmental stage.. Chickpea plant height was not significantly affected by intercropping methods during the early stage (30 DAS), but substantial differences were discovered at the later stages (60 DAS and harvest). At 60 DAS and harvest, chickpea alone generated the tallest plant on a pooled basis. A smothering and shadowing impact was seen on the chickpeas after 30 DAS in the intercropping systems because the maize grew faster than the chickpeas during the whole growth period.[9]

Chaudhary, R. S. (2018) Centurion University of Technology and Management in Odisha, with its typical sub-humid and subtropical climatic conditions, ran an experiment on a maize-legume intercropping system this past summer. Without regard to the number of legumes planted in each row, they found that solo maize generated the tallest plants. They also found that the intercropping strategy affected dry matter accumulation (g/plant) in both maize and legumes. Dry matter accumulation (176.12 g/plant) for sole maize was statistically equivalent to that of maize intercropped with groundnut (2:2 additive series), and substantially higher than that of any other combinations.[10]

Barik E., and P. K. Roul. (2017) During the kharif seasons of 2015 and 2016, on the medium black soils of the University of NanguiAbrogoua in Abidjan, Cote Divoire, a field experiment was conducted to examine the effect of spatial row arrangement on the agromorphological responses of maize and cowpea in an intercropping system. The maize and cowpea (2:4) arrangement was shown to be significantly more productive than solo and other spatial row layouts in terms of plant height, cob length, cob weight, selling percentage of maize harvest, number of pods per plant, and number of seeds per pod.[11]

Chhetri, B. and A. C. Sinha. (2016).A field experiment was conducted at the University of Agricultural Sciences in Dharwad (Karnataka) during the kharif season of 2015 on medium black soil to see how the planting pattern of maize with a field pea intercropping system affects yields. Green pods / plant, number of pods / plant, and number of seeds / pod were discovered under solitary field pea, whereas in the maize + field pea (1:1) intercropping system, plant height, cob length, cob weight, test weight, and selling % of maize crop were greatly enhanced.[12]

3. Methodology

The study examine the viability of a rabi maize (Zea mays L.) - chickpea (Cicer arietinum L.) intercropping system in medium Gujarat conditions, as well as the impact of residue management on the subsequent summer greengram (Vigna radiata L.).

3.1 Experimental site

Anand Agricultural University in Anand, Gujarat, had a field experiment on rabi maize-chickenpea intercropping systems and its residual management on summer greengram in plot no. 34 A during the 2018–19 and 2019–20 growing seasons at the College Agronomy Farm.

3.2 Varietal description

3.2.1 Maize

The current study employed as a test crop the maize variety GAYMH 3, which was issued in 2018 by the Main Maize Research Station at the Anand Agricultural University in Godhra for the middle Gujarat Agro-Climatic Zone. The 97-110 day maturity period is typical for this cultivar. In the field, this type also proves to be very resistant to stem borer. The cultivar has a theoretical yield of 65-66 q/ha.

3.2.2 Chickpea

For this study, we focused on the chickpea strain known as Gujarat Junagadh Gramme 3 (GJG 3). In 2018–19, the Pulse Research Station at JAU in Junagadh developed and released the chickpea cultivar GJG 3 for widespread planting in Gujarat.

In order to examine the long-term effects of the maize-chickpea intercropping system on the subsequent summer greengram crop, the Gujarat Anand Mungbean 5 (GAM 5) variety was employed after harvest. The Pulse Research Station of the Ahmedabad Agricultural University in Vadodara (Gujarat) introduced this new type for farmers to use. The kharif and summer seasons may both make use of this cultivar.

3.3 Experimental details

The methods used in the experiment on the "Feasibility of rabi maize (Zea mays L.) - chickpea (Cicer arietinum L.) intercropping system and impact of its residual management in succeeding summer greengram (Vigna radiata L.) under middle Gujarat condition" in the 2018–19 and 2019–20 growing seasons are described in detail.

Treatment	Treatmentdetails
	***Rabi*Season- RandomizedBlockDesign**
T_1	SoleMaize
T_2	SoleChickpea
T_3	Additive series of maize and chickpeas at a 1:1 ratio
T_4	Substitute Maize for Chickpeas (1:1)
T_5	Two-to-one mashup of corn and chickpeas (45-by-90-by-45 cm)
T_6	Pair of Maize and Chickpea Plants (45-90-45 cm)
	SummerSeason-Main plotspiltintotwosubplots
R_0	NoResidue
R_1	AddedResidue

3.4 Cropping pattern adopted during experimentation

To examine the long-term impact of treatments on maize-chickpea intercrop yields, an experiment was undertaken in 2018–19 and 2019–20, with maize cultivated during the rabi season and greengram planted in the summer. After harvesting the rabi maize and chickpea intercrops, the greengram was drilled as a subsequent summer crop to test the residual effects of the treatments. This was done by leaving the field fallow during the kharif season, which occurred between the two years of experimental planting. In both years, the crop was planted in all 48 plots without the use of fertilizer or other chemical enhancements.

3.5 Statistical analysis

Analyses of variance were performed on the data collected. The 'F' test was used to compare the outcomes of the treatments across all of the characters. Randomized block design and split plot design were used to evaluate the data from the previous maize-chickpea intercrop and the subsequent greengram.

Where significant differences were observed across treatments using the 'F' test, the critical difference (CD) at 5% was computed; otherwise, just the standard error of the mean was determined. Only critically important interactions were shown. For each character, the standard error of the mean and coefficient of variation were calculated so that an approximation of the level of accuracy could be made.

4. Results

Results from a study titled "Feasibility of rabi maize (Zea mays L.) - chickpea (Cicer arietinum L.) intercropping system and impact of its residual management in succeeding summer greengram (Vigna radiata L.) given, and then studied critically in light of the cause-and-effect correlations revealed by the work of other researchers under the heading "middle Gujarat condition.".

4.1 Population response to treatment in plants

Table 4.1: The effect of intercropping methods on the 15-day-old plant populations of maize and chickpea

Treatments	Plantpopulation/meterrowlengthat15DAS					
	Maize			Chickpea		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Intercroppingsystem						
T_1:SoleMaize	5.75	5.58	5.66	--	--	--
T_2:Sole Chickpea	--	--	--	10.51	10.18	10.35
T_3:Maize+chickpea(1:1) Additiveseries	5.63	5.73	5.68	10.18	10.13	10.15
T_4:Maize+chickpea(1:1) Replacement series	5.43	5.55	5.49	10.17	9.84	10.00

T_5:Plantain with maize (2:1) Parallel set (45 x 90 x 45)		5.63	5.75	5.69	10.49	10.04	10.27
T_6:Plantain and maize(2:2) Parallel set (45 x 90 x 45)		5.35	5.73	5.54	10.15	9.95	10.05
S.Em.±	Y			0.13			0.16
	T	0.29	0.26	0.19	0.37	0.38	0.27
	Y× T			0.27			0.37
C.D.at 5 %	Y			NS			NS
	T	NS	NS	NS	NS	NS	NS
	Y× T			NS			NS
C.V.%`		8.78	7.87	8.33	7.23	7.54	7.39

Table 4.2: The effect of intercropping methods on the 15-day-old maize and chickpea plant populations

Treatments		**Plantpopulation/netplotat15DAS**					
		Maize			**Chickpea**		
		2018-19	**2019-20**	**Pooled**	**2018-19**	**2019-20**	**Pooled**
Intercroppingsystem							
T_1:SoleMaize		274	283	279	--	--	--
T_2:Sole Chickpea		--	--	--	1102	1093	1099
T_3:Maize+chickpea(1:1) Additiveseries		278	285	281	481	485	483
T_4:Maize+chickpea(1:1) Replacement series		154	157	155	243	239	242
T_5:Plantain with maize (2:1) Parallel set (45 x 90 x 45)		243	241	242	240	236	238
T_6:Plantain and maize (2:2) Parallel set (45 x 90 x 45)		244	245	244	418	423	421
S.Em.±	Y			2.32			5.24
	T	5.05	5.32	3.67	11.86	11.62	8.30

	Y× T			5.19			11.73
C.D.at 5 %	Y			NS			NS
	T	15.56	16.39	10.70	36.54	35.80	24.23
	Y× T			NS			NS
C.V.%`		8.78	7.87	8.33	7.23	7.54	7.39

The growth, qualities, and yield of a maize crop are all affected by a number of variables, one of the most significant being plant population. The plant's population has a direct effect on the harvest's final yield. The highest possible yield can only be achieved by keeping the experimental field's plant population at its optimal level. Growth factors, yield qualities, and yield are all directly and negatively impacted by both higher and lower plant populations.

Table 4.1 shows the effect of several intercropping techniques on the number of maize plants at 15 DAS and at harvest in 2018–19, 2019–20, and a pooled basis.

At 15 days after planting and at harvest, the present research found no statistically significant differences between the intercropping systems of rabi maize and chickpea (Table 4.1). It might be because all of the seeds were planted at the same time using the same technique (the drilling method, in this case). This suggests that the seedlings in the experiment germinated at the same rate in both years.

Table 4.2 displays information collected for the 2018–19, 2019–20, and pooled years on the maize / net plot plant population as affected by various intercropping strategies at 15 DAS and at harvest.

Different rabi maize - chickpea intercropping methods were observed to significantly affect plant population/net plot at 15 DAS and at harvest (Table 4.2).

Table 4.2 displays the plant population per net plot at 15 DAS for each treatment, showing that the T1 (single maize) and T3 (maize + chickpea 1:1 Additive series) treatments had considerably greater plant populations in the first year, second year, and on a pooled basis. T4 (maize + chickpea 1:1 Replacement series) had the lowest plant population over both years and across all experiments combined.

The chickpea plant population per metre of row length at 15 DAS and at harvest in 2018–19, 2019–20, and the pooled data for both years is shown in Table 4.1.

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Neither the intercropping strategies examined separately nor the combined analysis of data from both years had any effect on the chickpea plant population per metre of row length at 15 DAS or at harvest (Table 4.1). Each plot in the experiment had the same density of single and intercropped chickpea plants per metre of row.

Table 4.2 compares the population of chickpea plants in the net plot at 15 DAS and at harvest under three different intercropping techniques in 2018–19, 2019–20, and a pooled scenario.

Table 4.2 shows that in both 2018–19, 2019–20, the plant population per net plot at 15 DAS was considerably greater under the T2 (single chickpea) treatment compared to the pooled basis. In contrast, T5 (maize + chickpea 2:1 paired row) had the lowest plant population in both years and throughout all experiments.

4.2Yield and quality characteristics as a result of treatment

Table 4.3: Differences in maize cob girth and cob length across intercropping methods

Treatments		**Cobgirth(cm)**			**Coblength(cm)**		
		2018-19	**2019-20**	**Pooled**	**2018-19**	**2019-20**	**Pooled**
Intercroppingsystem							
T_1:SoleMaize		17.43	16.70	17.07	22.61	24.69	23.65
T_2:Sole Chickpea		--	--	--	--	--	--
T_3:Additive series with maize and chickpeas (1:1)		18.76	18.39	18.58	23.55	25.10	24.33
T_4:Maize+chickpea(1:1) Replacement series		17.37	17.84	17.60	20.04	21.38	20.67
T_5:Plantain with maize (2:1) Parallel set (45 x 90 x 45)		15.26	15.06	15.16	19.98	21.53	20.75
T_6:Plantain and maize (2:2) Parallel set (45 x 90 x 45)		15.96	15.57	15.77	19.14	20.90	20.02
S.Em.±	Y			0.34			0.45
	T	0.75	0.77	0.54	1.01	0.98	0.70
	Y× T			0.76			1.00

C.D.at 5 %	Y			NS			1.32
	T	2.31	2.38	1.57	3.13	3.01	2.06
	Y× T			NS			NS
C.V.%`		8.85	9.25	9.05	9.46	8.45	8.94

Grain yield was shown to be positively and significantly correlated with cob girth. Grain yield was shown to be positively influenced by cob girth, test weight, plant height, number of grains per row, and number of cobs per plant, according to the path analysis. Table 4.3 shows the effects of several intercropping tactics on girth-of-cob at harvest time for 2018–19, 2019–20, and a combined total.

Table 4.3 compiles and analyses data on cob girth from many years to illustrate the large impact of intercropping systems on cob girth. Treatment T3 maize + chickpea 1:1 Additive series had significantly higher cob girth (18.76, 18.39, and 18.58 cm) than the other treatments in both 2019 and 2020, and when the data were combined.. With regards to maize cob girth, however, treatment T1 (maize alone) and T4 (maize + chickpea 1:1 Replacement series) showed no significant difference. Treatment T5 (maize and chickpea in a 2:1 paired row) yielded the smallest cob girth throughout all three years and in the pooled study (15.26, 15.06, and 15.16 cm).

A positive source to sink connection may explain why the cob girth was much greater during the T3 (maize - chickpea 1:1 Additive series) treatment. In addition, growth indicators indicated that the maize crop grew more rapidly than the intercropped chickpea. Additionally, adequate row-to-row spacing in maize crops may reduce intra-row and intra-crop competition. Chickpea's symbiotic nitrogen fixing of atmospheric nitrogen benefited the maize crop. Negative partitioning of photosynthesis in maize may occur if the crop is exposed to resource competition, as seen in Treatments T5 (maize + chickpea 2:1 paired row) and T6 (maize + chickpea 2:2 paired row).

Table 4.4: The effect of intercropping methods on chickpea nodule counts

Treatments	**Numberof nodules/ plant(35DAS)**		
	2018-19	**2019-20**	**Pooled**
Intercroppingsystem			
T_1:SoleMaize	--	--	--

T_2:Sole Chickpea		17.97	19.09	18.53
T_3:Maize +chickpea(1:1) Additiveseries		10.52	10.48	10.50
T_4:Maize +chickpea(1:1) Replacementseries		12.17	13.98	13.08
T_5:Plantain with maize (2:1) Parallel set (45 x 90 x 45)		10.66	12.39	11.53
T_6:Plantain and maize (2:2) Parallel set (45 x 90 x 45)		9.80	11.02	10.41
S.Em. ±	Y	--	--	0.29
	T	0.61	0.71	0.47
	Y× T	--	--	0.66
C.D.at 5 %	Y	--	--	NS
	T	1.88	2.17	1.36
	Y× T	--	--	NS
C.V.%`		9.98	10.54	10.30

The number of nodules per plant influences growth, symbiosis characteristics, yield attributes, yield, nutrient absorption, and quality in chickpea and other leguminous crops. Rhizobial biological nitrogen fixing and phytohormone synthesis have been linked to this enhanced nutrient uptake. The quantity of nodules per plant is very sensitive to changes in soil variables including pH, nutrient availability, soil temperature, herbicide, and moisture. Table 4.4 displays, for the years 2018–19, 2019–20, and in a pooled analysis, the number of nodules per plant in the chickpea crop as affected by intercropping methods.

Analysing the chickpea crop's nodules per plant at 35 DAS across 2018–19, 2019–20, and pooled data shows substantial heterogeneity owing to various intercropping strategies. The number of nodules per plant was greatest for Treatment T2 (single chickpea) in all three years at 17.97, 19.09, and 18.53. Treatment T6 (maize + chickpea 2:2 paired row) yielded the lowest number of nodules per plant (9.80, 11.02, and 10.41) in all three years combined.

4.3 Effect of residue management on succeeding summer greengram

We harvested our greengram crop following our maize and chickpea intercrops. Various characteristics of development and fruition.

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Table 4.5: Intercropping and crop residue management's effects on the subsequent green gram plant population at 15 DAS

Treatments	Plantpopulation/meterrowlengthat15DAS		
	2019	**2020**	**Pooled**
Intercroppingsystem(T)			
T_1:SoleMaize	9.33	9.25	9.29
T_2:Sole Chickpea	9.58	9.41	9.49
T_3:Maize +chickpea(1:1) Additiveseries	9.71	9.26	9.49
T_4:Maize +chickpea(1:1) Replacementseries	9.36	9.33	9.34
T_5:Plantain with maize (2:1) Parallel set (45 x 90 x 45)	9.46	9.63	9.54
T_6:Plantain and maize (2:2) Parallel set (45 x 90 x 45)	9.44	9.39	9.41
S.Em.$\pm$	0.15	0.14	0.10
C.D.at 5 %	NS	NS	NS
C.V.%	4.56	4.27	4.42
CropResiduemanagement(R)			
R_0:NoResidue	9.47	9.31	9.39
R_1:AddedResidue	9.49	9.45	9.47
S.Em.$\pm$	0.08	0.08	0.06
C.D.at 5 %	NS	NS	NS
Interactioneffect(T x R)	--	--	--
Year (Y)	9.48	9.38	----
S.Em.$\pm$	--	--	0.14
C.D.at 5 %	--	--	NS
C.V.%	4.22	4.14	4.18

Table 4.6: The effect of intercropping and crop residue management on the harvest plant population of subsequent greengram

Treatments	Plantpopulation/meterrowlengthatharvest		
	2019	**2020**	**Pooled**
Intercroppingsystem(T)			
T_1:SoleMaize	8.78	8.44	8.61

T_2:Sole Chickpea	8.76	8.61	8.69
T_3:Maize +chickpea(1:1) Additiveseries	8.45	8.46	8.46
T_4:Maize +chickpea(1:1) Replacementseries	8.55	8.65	8.60
T_5:Plantain with maize (2:1) Parallel set (45 x 90 x 45)	8.51	8.83	8.67
T_6:Plantain and maize (2:2) Parallel set (45 x 90 x 45)	8.58	8.66	8.62
S.Em. ±	0.14	0.15	0.10
C.D.at 5 %	NS	NS	NS
C.V.%	4.74	4.89	4.82
CropResiduemanagement(R)			
R_0:NoResidue	8.59	8.52	8.56
R_1:AddedResidue	8.60	8.70	8.65
S.Em. ±	0.08	0.07	0.05
C.D.at 5 %	NS	NS	NS
Interactioneffect(T x R)	--	--	--
Year (Y)	8.59	8.61	--
S.Em. ±	--	--	0.13
C.D.at 5 %	--	--	NS
C.V.%	4.65	4.09	4.38

Crop growth, yield qualities, and yield are all heavily influenced by the plant population (crop stand). The population of plants has a direct effect on the harvest. The highest possible yield can only be achieved by keeping the experimental field's plant population at its optimal level. Growth, yield characteristics, and yield are all negatively impacted by either a high or low plant population.

Tables 4.30 and 4.31 present pooled data for 2019 and 2020 on plant population (per metre row length) of succeeding green gramme recorded at 15 DAS and at harvest, respectively, as influenced by the residual effect of the intercropping system in rabi maize + chickpea. There was little to no difference in the plant populations in 2019 and 2020, or between the populations pooled at 15 DAS and at harvest.

According to the data shown in both tables, the influence of crop residue management and their interaction had no major impact on the plant population of subsequent greengram at 15 DAS and at harvest across both years and in combined findings.

5. Conclusion

Based on the results of the research, intercropping maize with chickpea at a 1:1 ratio (Additive series) results in the highest possible grain production and maize equivalent yield. Summer greengram cultivation in the residual effect of chickpea sole with crop residue management practises (added residue) increased seed production, haulm output, and financial returns. The best nett returns and BCR were achieved by growing maize and chickpeas in a 1:1 ratio (Additive series), then growing greengrams in the residue. This method significantly reduced the cost of fertiliser for the greengram crop and improved soil quality.

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