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Growth Attributes, Yield Attributes and Yield of Groundnut as Influenced by Intensification Through Groundnut (*Arachis hypogaea* L.)- Sweet Corn (*Zea mays* var. *saccarata*) Intercropping System

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ABSTRACT

Background: Second-generation issues facing by Indian agriculture today are changing water tables, nutrient and disease imbalances, contamination of the environment and declining output from agriculture so there is a urgent need to enhance crop productivity to ensure food security.

Methods: In this field study, groundnut and sweet corn were used as a test material under ten treatments, including sole groundnut; sole sweet corn; groundnut + sweet corn in 1:1; 2:1 and 3:1 row ratio in both replacement and additive series; mix sowing of groundnut 80% + sweet corn 20% and groundnut + sweet corn in (2:1) with paired row (30-60-30 cm) at Regional Rice Research Station, Navsari Agricultural University, Vyara, Gujarat (India) during the summer season of the year 2020-21 and 2021-22. Data on growth attributes, yield attributes and yield of both the crops were recorded.

Result: The results showed that significant reduction in growth, yield attributes and yield of groundnut were observed under mix/intercropping systems as compared to sole groundnut. Among the mix/ intercropping systems, intercropping of groundnut + sweet corn in (2:1) with paired row (30-60-30 cm) was found superior in terms of the pod yield as well as haulm yield, the productivity and biological efficiency of these systems in terms of groundnut pod equivalent yield (3221 kg/ha), land equivalent ratio (1.88) and area time equivalent ratio (1.75). Crop intensification through groundnut + sweet corn in (2:1) with paired row (30-60-30 cm) or groundnut + sweet corn in (3:1) in additive series could be adopted for obtaining higher groundnut pod equivalent yield.

Key words: ATER, GPEY, Growth, LER, Yield.

INTRODUCTION

Grown in more than 100 nations across the world's tropics and subtropics, groundnuts are a crop of global significance. China ranks first in groundnut production with 18.36 million tonnes followed by India 10.24 million tonnes, Nigeria 4.61 lakh tonnes, United States of America 2.90 million tonnes and Sudan 2.36 million tonnes (Anonymous, 2021). India's agricultural economy is based primarily on groundnuts, which have long been an essential oilseed crop. India produced 10.11 million tonnes of groundnuts on 5.75 million hectares of land, with a productivity of 1759 kg/ha (Anonymous, 2022).

In order to compete globally in a variety of agricultural commodities, India's agriculture must overcome new obstacles in the evolving global agricultural scenario. Second-generation issues facing by Indian agriculture today are changing water tables, nutrient and disease imbalances, contamination of the environment and declining output from agriculture. The national agrarian distress that began in 1990 was primarily caused by the low level of absolute income and the growing income disparity between farmers and non-agricultural workers, which has gotten even worse in recent years. In light of this, doubling farmers' income by 2022-2023 may prove to be a crucial goal for advancing farmer welfare, easing agrarian hardship and establishing wage parity between farmers and non-farmers.

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The primary factors driving growth in the agricultural sector are increases in productivity, resource efficiency or cost savings in production; moreover, intensification and crop diversification toward high-value crops to support increased farm income and profitability are also important.

Increasing the yield from a given area by growing two or more crops on the same field in a single year is known as crop intensification. Through crop intensification, one can maximize crop output per unit area and time while

ensuring food security, self-sufficiency, crop failure insurance and resource efficiency.

In regard to the myriad issues confronting modern agriculture and the urgent need to boost crop output in order to guarantee food security for all, sustainable crop intensification techniques like intercropping and mixed cropping must be encouraged. Monocropping systems have minimum benefits which lead to low crop production and a higher probability of crop failure (Prakash *et al.,* 2024). Intercropping is an age old practice in India, especially under rainfed conditions, which aims to increase total productivity per unit area and to equitably and judiciously utilize land resources and farming inputs including labour (Mohapatra *et al.,* 2013 and Sharmili *et al.,* 2021). By utilizing all available resources to the fullest extent that a single crop could not, legume-based intercropping seeks to increase yield from a unit area (Zhang *et al.,* 2011).

In this area, crop diversity is necessary and should be both profitable and providing feed. A groundnut and sweet corn intercropping strategy is perfect. Sweet corn has the advantage of producing green fodder and being harvested 80-90 days after seeding, increasing the intensity of annual cropping overall.

If small and marginal farmers in this area have access to information about the best groundnut-based inter/mix cropping systems, crop intensification could result in stabilized production and profits. Thus, a thorough investigation of crop intensification using groundnut + sweet corn intercropping systems was suggested.

MATERIALS AND METHODS

Crop cultivars

The groundnut variety Gujarat Groundnut-5 (GG-5) was used for this study as base crop, while sweet corn variety Sugar-75 as intercrops.

Experimental location and design

In the tropical, warm and humid climate zone (South Gujarat Heavy Rainfall Zone-I, Agro Ecological Situation III), at the coordinates of 21.12°N and 73.4°E, the experiment was carried out on clayey texture soil at the Regional Rice Research Station, Navsari Agricultural University, Vyara, Gujarat during the summer season of the year 2020-21 and 2021-22. The experiment soil was medium in organic carbon (0.75 and 0.74%), available nitrogen (296.3 and 307.1 kg/ha), available phosphorus (32.3 and 34.3 kg/ha), available potash (289.3 and 293.4 kg/ha) and neutral in reaction with pH (7.26 and 7.55) and EC (0.31 and 0.32 dS/m). The trial was set up in a randomized block design following three replications with 10 treatments.

Experiment setup

In this experiment, the both replacement and additive series of intercropping were used. There were ten treatments including sole groundnut (T_1), sole sweet corn (T_2), groundnut + sweet corn in 1:1 (T_3), 2:1 (T_4) and 3:1 (T_5) row ratio in replacement series; groundnut + sweet corn in 1:1 (T_6), 2:1 (T_7) and 3:1 (T_8) row ratio in additive series; mix sowing of groundnut 80% + sweet corn 20% (T_9) and groundnut + sweet corn (2:1) with paired row (30-60-30 cm) (T_{10}). There were 3 plots for each treatment and a total of 30 plots in this experiment. In addition, the row spacing of groundnut and sweet corn were all 45 cm but hill spacing of groundnut and sweet corn were 10 cm and 20 cm, respectively; groundnut each hole one plant, sweet corn each hole two plants. Moreover, gross plot size of 5.4 m × 6.0 m and their respective net plot size of 3.6 m × 5.2 m for sole groundnut; sole sweet corn; groundnut+ sweet corn (1:1) in replacement series and (1:1) and (2:1) in additive series and mix sowing of 80% groundnut+ 20% sweet corn, net plot size of 2.7 × 5.2 m for groundnut+ sweet corn (2:1) in replacement series and 4.2 × 5.2 m for groundnut+ sweet corn (2:1) in paired row (30-60-30 cm) whereas, gross plot size of 5.85 m × 6.0 m and net plot size of 4.05 m × 5.2 m for groundnut + sweet corn (3:1) in replacement series and additive series, respectively and there was 1.0 m spacing between neighboring plots. After the previous crop was harvested, the experimental land was tractor-plowed, harrowed once to break up any clods, then planked to a fine tilth before seeding. To keep the field prepared for seeding, furrows were opened and the field was divided into plots in accordance with the layout. In the form of urea and diammonium phosphate, the full recommended dosages of fertilizer (25-50-00 NPK kg/ha) for groundnut as per sole and intercrops based on area occupied were applied as basal application. Just prior to seeding in the furrows, urea, diammonium phosphate and muriate of potash were given as a basal application for sweet corn, whereas the full dose of potassium, phosphorus and half of the nitrogen dose (50-50-50 NPK kg/ha) were given to intercrops based on area occupied. At 30 days after sowing (DAS), the remaining half of the nitrogen dosage (50 kg/ha) was top-dressed with urea.

During the *Rabi* season of 2021 and 2022, groundnut and sweet corn were sown on December 27th and January 1st, respectively, with a seed rate of 100 and 10 kg/ha. The groundnut seeds were treated with Mancozeb at a rate of 3 g/kg seed, placed at a depth of 5 cm, with the interrow spacing maintained in accordance with the treatment and lightly covered with soil. At 15-20 DAS, the seedlings were thinned to maintain the intrarow spacing and necessary plant population. Wherever there was a gap, gap filling operation was also completed concurrently. Throughout both seasons, a single hand weeding was done. To keep the experimental field free of weeds for both years, a single interculturing operation carried out at 28 DAS. Emamectin benzoate 1.9% EC @ 20 ml/15 litre was sprayed in the experiment plots once in 2020-21 and twice in 2021-22 to suppress fall Armyworm in sweet corn crop.

RESULTS AND DISCUSSION

Effect of intercropping on growth attributes

The data on growth attributes of groundnut are presented in Table 1. An appraisal of data revealed that growth

attributes of groundnut were significantly influenced by mix/ intercropping system in pooled results of both the years 2020-21 and 2021-22.

Among the different treatments, sole groundnut (T_1) had recorded significantly the highest growth attributes of groundnut *viz*., final plant population (22.26 plants/m^2), number of branches/plant (7.97), dry matter production/ plant (37.37 g) and number (80.9) and fresh weight (3.75 g) of root nodules/plant. Whereas, significantly highest plant height (67.84 cm) was recorded with intercropping systems of groundnut + sweet corn (1:1) in additive series (T_6) and maximum leaf area/plant (2911.4 cm^2) and leaf area index (6.470) of groundnut at harvest was recorded in paired row sowing of groundnut + sweet corn (2:1) at 30-60-30 cm (T_{10}) in pooled results. Intercropping treatments did not show their significantly effected on plant spread.

In additive intercropping systems final plant populations were comparably reduced over the sole cropping. This might be due to competition for sunlight, space and nutrients between the groundnut and sweet corn in additive intercropping systems as compared to sole groundnut. In replacement intercropping systems final plant populations were comparably reduced over the sole groundnut due to groundnut row replaced by intercrop based on row proportions (Konlan *et al.,* 2013 and Baishya *et al.,* 2021).

Significantly lowest number of branches per plant, reduced leaf area, dry matter as well as leaf area index of groundnut was recorded under intercropping systems of groundnut + sweet corn (1:1) in additive series (T_6) might be severe competition for resources by intercrop with groundnut, which made poor utilization of sunlight, space and nutrients between the groundnut and sweet corn in the intercropping system, consequently growth was suppressed owing to reduced photosynthesis and partitioning of photosynthates (Polthanee and Vidhaya, 2003; Ghosh, 2004; Inal *et al.,* 2007; Mandal *et al.,* 2014 and Konlan *et al.,* 2015). Sweet corn has a significant effect on groundnut nitrogen fixation traits in intercropping systems (Zhang *et al.,* 2024). Poor nodulation in groundnuts may be the result of less light owing to shade (Nambiar *et al.*, 1982). By limiting photosynthesis and the energy supply to roots, this decreased light energy impacts N2 fixation. This lowers nodulation and nodule size, which in turn results in lower fresh weight of root nodules per plant in intercropping regimens.

The height of the plant was significantly highest under intercropping systems of groundnut + sweet corn (1:1) in additive series (T_6) might be due to shading imposed on the groundnut by the sweet corn leads to lengthening of the groundnut internodes in order to capture sunlight. The taller groundnut plants observed in the groundnut-sweet corn association were probably a consequence of light and space competition with the sweet corn (Musthapha *et al.,* 2016).

Effect of intercropping on yield attributes and yield

An appraisal of data on yield attributes and yield are presented in Table 2 indicated that which was significantly influenced by various mix/intercropping systems in pooled results of both the year of 2020-21 and 2021-22.

The sole groundnut (T_1) had significantly the highest 100-kernel weight (41.0 g), shelling percentage (70.32%),

Table 1: Growth attributes of groundnut as influenced by groundnut based mix/intercropping systems.

Treatment	Plant population (m^2)	Plant height (cm)	Plant spread (cm)	No. of branches/ plant	Dry matter/ plant (g)	No. of root nodules/ plant	Fresh wt. of nodules/ plant (g)	Leaf area/ plant (cm^2)	Leaf area index
T_1	22.26	56.88	40.12	7.97	37.37	80.9	3.75	2323.8	5.164
T_2	-	-	-	-	-	-	-	-	-
T_3	11.11	52.52	35.66	6.43	25.80	64.3	3.07	1722.7	3.828
T_4	14.76	60.73	36.57	7.30	31.47	64.6	3.19	2334.7	5.188
T_5	15.29	62.39	37.42	6.93	36.00	76.1	3.58	2542.7	5.650
T_6	22.22	67.84	33.73	5.77	21.97	61.4	2.90	1427.8	3.173
T_7	22.14	59.23	35.35	6.47	27.53	69.7	3.17	2109.7	4.688
T_8	22.10	61.85	36.05	7.03	28.47	79.0	3.42	2473.1	5.496
T_9	17.70	62.94	35.37	7.37	27.53	72.1	3.08	2205.6	4.901
T_{10}	22.18	52.51	36.67	7.03	34.42	76.1	3.14	2911.4	6.470
S.Em.±	0.77	3.85	1.35	0.29	1.40	2.55	0.10	180.75	0.402
C.D.	2.22	5.82	NS	0.85	4.55	7.34	0.30	589.46	1.310
C.V. %	10.00	8.29	9.12	10.41	6.42	8.72	7.85	10.76	11.36
Year									
S.Em.±	0.02	1.14	0.35	0.14	0.66	0.86	0.03	85.21	0.189
C.D.	NS	3.27	1.01	0.40	1.9	NS	0.08	245.45	0.545
Y × T									
S.Em.±	1.09	2.86	1.91	0.42	1.11	3.6	0.15	138.41	0.308
C.D.	NS	NS	NS	NS	3.21	NS	NS	398.71	0.886

number of pods/plant (20.9), pod yield (1831 kg/ha) and haulm yield (3478 kg/ha) and which was remain statistically at par with treatments intercropping of groundnut + sweet corn (2:1) in replacement series (T_4), groundnut + sweet corn (3:1) in replacement series (T_5), groundnut + sweet corn (3:1) in additive series (T_8) and paired row sowing of groundnut + sweet corn (2:1) at 30-60-30 cm (T_{10}) (Except, treatment T_4 in 100-kernel weight, treatments T_4 and T_8 in number of pods/plant and treatments T_4 and T_5 in pod and haulm yield) which may be due to sole crop enjoyed higher availability of nutrient, moisture, light, space *etc.* and improved yield attributes and finally gave higher crop yield (Baishya *et al.,* 2021). Overall yield reduction of groundnut was observed under mix/intercropping situation when compared with sole cropping. Whereas, harvest index (35.21), groundnut pod equivalent yield (3221 kg/ha), land equivalent ratio (1.88) and area time equivalent ratio (1.75) were recorded significantly the highest under paired row sowing of groundnut + sweet corn (2:1) at 30-60-30 cm (T_{10}) and which was remain statistically at par with treatments T_8 in pooled results (Table 2). The land equivalent ratio of 1.88 signifies that a sole cropping system would need 88% more space to achieve the yield of an intercropping system. Additionally, it indicates that mix/ intercropping systems are more biologically sustainable than sole cropping. Because area time equivalent ratio takes into account the variation in time utilized by the component crops of different mix/intercropping systems, it offers a more realistic comparison of the yield benefit of intercropping over that of sole cropping than does LER. The groundnut + sweet corn intercropping system's ATER was greater than one under all treatments (treatments T_2, T_3 and T_6) indicating the benefit of mix/intercropping systems. On the other hand, the ATER was less than one, indicating that the intercropping system did not maximize the use of all resources (Kathmale *et al.,* 2014; Rajaii and Dahmardeh, 2014; Sutharsan and Srikrishnah, 2015; Musthapha *et al.,* 2016; Kithan and Longkumer, 2017; Telkar *et al.,* 2018; Chovatia *et al.,* 2020 and Baishya *et al.,* 2021).

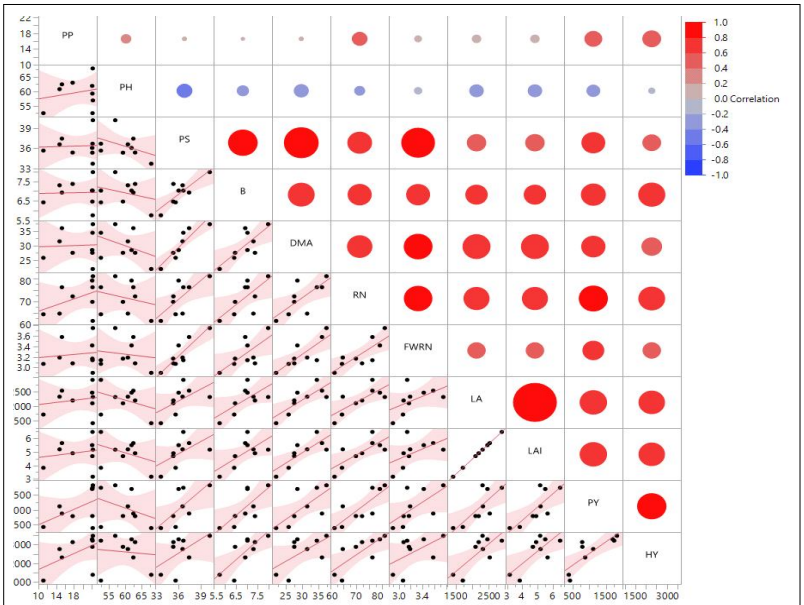
The presence of groundnut in the paired row system probably had more synergistic effect as compared to antagonistic effect as well as more space available to groundnut plant which increase photosynthetic activities and resulted in higher growth and yield attributes which ultimately reflected in yield of groundnut (Jana and Saren, 1998; Polthanee and Vidhaya, 2003; Ghosh, 2004; Bhagat *et al.,* 2007; Dutta and Bandyopadhyay, 2006; Konlan *et al.,* 2013; Mandal *et al.,* 2014; Shwethanjali *et al.,* 2018; Sepat *et al.,* 2019; Das *et al.,* 2020; Baishya *et al.,* 2021 and Abba *et al.,* 2024).

The relationship between the pod yield of groundnut and other important growth, yield attributes and haulm yield has been studied. The data on correlation (r) are graphically shown in Fig 1 and 2.

Result revealed that growth attributes *viz.*, number of root nodules per plant and yield attributes *viz.*, 100-kernel weight and number of pods per plant and haulm yield of groundnut showed positive and highly significant correlation with pod yield of groundnut. While plant height at harvest shown their negative correlation with pod yield in pooled result.

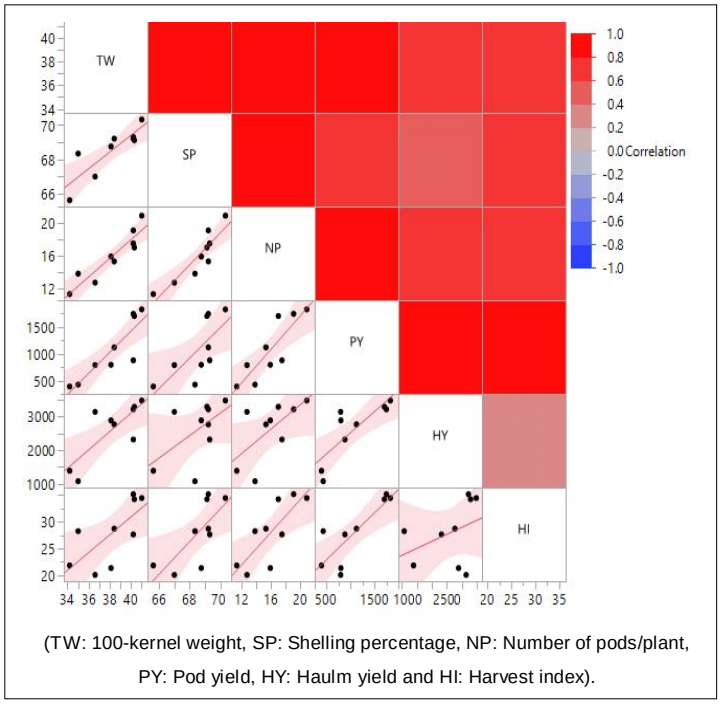
Table 2: Yield attributes of groundnut as influenced by groundnut based mix/intercropping systems.

Treatment	Test weight (g)	Shelling percentage (%)	No. of pods/ plant	Pod yield (kg/ha)	Haulm yield (kg/ha)	Harvest index	Groundnut pod equivalent yield (kg/ha)	LER	ATER
T_1	41.0	70.32	20.9	1831	3478	34.48	1831	1.00	1.00
T_2	-	-	-	-	-	-	1605	1.00	0.86
T_3	35.0	68.34	13.8	426	1074	28.28	1832	1.11	0.99
T_4	38.4	69.21	15.3	1122	2766	28.74	2670	1.58	1.45
T_5	40.2	69.30	17.5	880	2316	27.66	2181	1.29	1.18
T_6	34.2	65.63	11.3	390	1385	21.84	1212	0.72	0.65
T_7	38.1	68.75	15.9	796	2886	21.35	2362	1.41	1.27
T_8	40.3	69.12	17.0	1707	3289	34.26	3073	1.79	1.67
T_9	36.6	67.00	12.7	791	3140	20.07	1936	1.15	1.05
T_{10}	40.2	69.21	19.1	1748	3216	35.21	3221	1.88	1.75
S.Em.±	0.92	0.50	1.13	43.61	90.96	1.19	64.66	0.04	0.04
C.D.	2.65	1.43	3.67	125.63	262.03	3.42	185	0.11	0.10
C.V. %	5.88	1.78	9.32	9.92	8.52	10.38	7.22	7.35	7.38
Year									
S.Em.±	0.08	0.08	0.53	16.99	34.49	0.59	24.38	0.01	0.01
C.D.	NS	NS	1.53	48.95	99.36	1.70	70	0.04	0.04
Y × T									
S.Em.±	1.30	0.70	0.86	61.68	128.64	1.68	91.44	0.05	0.05
C.D.	NS	NS	2.47	NS	NS	NS	NS	NS	NS



(PP: Plant population, PH: Plant height, PS: Plant spread, B: Number of branches/plant, DMA: Dry matter/plant, RN: Number of root nodules, FWRN: Fresh weight of root nodules, LA: Leaf area/plant, LAI: Leaf area index, PY: Pod yield and HY: Haulm yield).

Fig 1: Correlation between growth attributes of groundnut with pod yield.



(TW: 100-kernel weight, SP: Shelling percentage, NP: Number of pods/plant, PY: Pod yield, HY: Haulm yield and HI: Harvest index).

Fig 2: Correlation between yield attributes and haulm yield of groundnut with pod yield.

CONCLUSION

The study of summer groundnut-based mix/intercropping systems results that led to in the clayey soil of the heavy rainfall zone in south Gujarat, crop intensification could be achieved by either intercropping groundnut and sweet corn in paired row (30-60-30 cm) (2:1) or in additive series (3:1) to increase groundnut pod equivalent yield.

Conflict of interest

All authors declare that they have no conflict of interest.

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