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Effect of Cereal-Legume Intercropping, Tillage Configuration and Residue Intensity on Resource use Efficiency and Productivity

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ABSTRACT: Agriculture faces challenges such as climate change, water scarcity, and soil degradation, leading to low crop yields and exacerbating poverty and food insecurity. Rainfed ecologies face the multivariate challenges of climate change and resource deficit. Additionally, factor productivity and yield tend to decline with time-lapse. To address these challenges and improve sustainable food security, efficient technologies for intensifying crop production are an urgent necessity.

Present study was planned to investigate the challenges of monoculture problems throughout the Indo Gangetic plains region. Further reduce soil fertility and nutrient status due to intensive tillage and cereal based monoculture require modification for an effective cropping system. This study investigated the effects of different tillage configurations, residue retention levels, and row ratios on the growth, yield, and economic benefits of intercropped cowpea and cluster bean with pearl millet. SPAD Value, intercropping indices were calculated. Data analysis was performed using SAS 9.1 software and R studio software version 4.02.

The results show that reduced evapotranspiration of intercropped crops results in better water use efficiency, and high land equivalent ratio. The study highlights the importance of improving water and radiation use for better performance of intercropping systems. Treatment with Zero tillage with 4-ton residue ha^{-1} resulted into higher productivity and resources use efficiency in term of yield, crop growth and land use efficiency. This study provide the significant positive effect of zero tillage (soil health, climate resilience) and legume intensification (sustainability with productivity) over conventional practices.

Keywords: Intercropping, Legume intensification, Resource use efficiency, Zero tillage.

INTRODUCTION

Food production must increase to meet the needs of a growing population whilst minimizing impacts on the environment (Foley *et al*., 2011). A consensus emerges that this requires the Sustainable Intensification of agriculture (Tilman *et al.,* 2011; Garnett *et al*., 2013; Vanlauwe *et al*., 2014). Conservation agriculture (CA) has been highlighted as a key route to Sustainable Intensification (Pretty and Bharucha 2014). Low crop and cropping system yield in the rainfed ecologies exacerbated by water stress, poor infrastructure climate vagaries limiting farmers' access to higher productivity (Fonteyne *et al*., 2020; Choudhary *et al.,* 2021). In cereal-based cropping systems, diversification through crop rotations and intercropping is an important strategy to mitigate against climate risks and soil fertility decline (Smith *et al*., 2016; Thierfelder *et al*., 2012). Low yield in the rainfed and drylands of Asian continent are exacerbated by water stress and limiting farmers' access to irrigation. Agriculture plays a crucial role in global food security and is facing numerous challenges due to climate change, water scarcity, and soil degradation. These challenges have led to low crop yields, particularly in rainfed areas, exacerbating poverty and food insecurity in rural populations. To ensure sustainable food security and improve the livelihoods of impoverished communities, there is a pressing need to identify and evaluate efficient technologies for intensifying crop production in a sustainable manner, while reducing input requirements and increasing yields and productivity (Khan *et al.,* 2007; Lejissa *et al.,* 2022). Conservation agriculture (CA) is a strategy to increase crop yields and reduce water usage sustainably. With the advent of Conservation Agriculture (CA), based on the three principles of minimum soil disturbance, crop residue retention and crop diversification in the late 1990s, a lot of research efforts went into integration of leguminous crops adapted to no-tillage farming systems (Mupangwa *et al*., 2017; Gathala *et al*., 2015). Conservation agriculture (CA) has also been promoted in these areas as a mitigation measure and has been shown to be successful in improving yields Gupta *et al.,* 2022). CA is defined as a type of agriculture that uses natural resources more efficiently through integrated management of available resources. Tillage systems used in CA are widely recognized as a method of mitigating some of the negative effects of conventional tillage, such as soil erosion, pesticide leaching and runoff (Klik and Rosner 2020).

Intercropping is one such CA practice that involves growing two or more crops simultaneously in the same field. Cowpea and cluster bean are commonly used as intercrops in pearl millet-based cropping systems in arid and semi-arid regions (Eskandari *et al.,* 2009; Yadav *et al*., 2015; Tiwari *et al.,* 2015). Incorporating legumes into cereal-based systems replenishes soil fertility through nitrogen fixation while supplying protein-rich grains for household food and nutrition. Conservation agriculture (CA) practices, including reduced tillage options, have been successful in improving yields, resource use efficiencies, and soil and water quality while reducing production costs. However, the optimal tillage configuration, residue retention, and row ratio for intercropping cowpea and cluster bean in pearl millet-based cropping systems have not been fully explored.

Therefore, this study aims to investigate the effect of different tillage configurations (conventional tillage, Zero-tillage), residue retention levels (30%, and 60%), and row ratios (1:1, 1:2) on the growth, yield, and economic benefits of cowpea and cluster bean intercropped in pearl millet-based cropping systems. The findings of this study could inform the development of sustainable CA practices that enhance soil health, increase crop productivity, and promote economic benefits for smallholder farmers in arid and semi-arid regions.

MATERIALS AND METHODOLOGY

Study site description. The field trials were conducted on a sandy loam soil in two consecutive seasons of kharif over 2 years from 2020 to 2021 at the research farm of the Division of Agronomy, Indian Agricultural Research Institute, New Delhi. Geographically, the site lies little north latitude of 28°40'N and longitude of 77°12'E with an altitude of 228.6 m above the mean sea level.

Soil and Climate. This location has a typical semi-arid and sub-tropical climate characterized by hot dry summers and cool winters. The mean annual rainfall is 650 mm and more than 80% generally occurs during the south-west monsoon season (July to September) with mean annual evaporation of 850 mm. The rainfall received during the crop growing period from July to October was 615.3 mm in 2020 and 1484.2 mm in 2021 (Fig. 1). The experiment was conducted in the field no. '6F-Todapur Block' of the research farm of the Division of Agronomy, Indian Agricultural Research Institute, New Delhi, situated at 28°4′N latitude, 77°12′E longitude and at 228.6 m above mean sea level in a semi-arid climatic belt. The field had an even topography and fair drainage system. Soil of the experiment field belongs to the order inceptisol having sandy loam texture in upper 30 cm layer. Five representative soil samples 0-15 cm depth were collected from the experimental field prior to experimentation before sowing by using core sampler, then the samples were analysed for available major and micro nutrients and physio–chemical properties of soil. The soil of the experimental site was poor in organic carbon concentration, available nitrogen, phosphorus and potassium. Furthermore, the soil was slightly alkaline in reaction with pH (7.6) and the electrical conductivity (EC) observed 0.30 dS m^{-1} at 25 Celsius. The average numerical values for various parameters by routine procedures are given in (Table 1).

Experiment Design and Treatment Details. The experiment was laid out in Randomized complete block design and replicated thrice with total 12 treatments: comprising zero tillage with kharif residue and zero tillage with Rabi season residue. Different plant population density (row ratio) was aligned to the treatment to know the effect of intercropping configuration on yield and productivity. Each plot was measured as 7m × 4m (28 m^2) area. The cultivar use for the study was Cluster bean (RGC-936), Cowpea (Kashi Kanchan).

Plant and soil sampling. Sequential and final biomass harvests were conducted by hand at pearl millet flowering and final physiological maturity of both the crops. With 50 cm borders at each end (length ways within the row), harvests consisted of 100 cm of biomass of every plot row, except one border row on either side of the plot. These harvests involved scanning the leaves of five individual plants per plot to obtain the leaf area as well as dried biomass weights of plant parts separated into leaf, stem, and pod (cowpea) or Cluster bean.

Each plot was 5m × 4 m. One metre in length for all rows, excluding the two outer most rows (border rows), was used for the final harvest sample. Cluster bean and cowpea pods opened to obtain the true yield of each plot before being weighed. The remaining biomass was dried in ovens at 60°C for 48 h and weighed. Leaf Area Index (LAI –Table 1) was calculated using aleaf area meter and light interception for each plot.

Table 1: Soil physio chemical properties (Initial) of experiment field.

Parameters	Status	Method of analysis
A. Soil mechanical analysis		Modified hydrometer (Bouyoucos, 1951)
Sand (%)	60	
Silt (%)	12.66	
Clay (%)	25.86	
Soil texture class	Sandy loam	USDA texture triangle
B. Soil physical analysis		
Field capacity (%)	18.73	Pressure plate apparatus (Richards,1954)
Permanent wilting point (%)	6.51	Pressure membrane apparatus (Richards, 1954)
Bulk density (Mg m^{-3})	1.54	Core method (Piper, 1966)
Infiltration rate (cm hr^{-1})	1.08	Double ring infiltrometer (Rana *et al*., 2014)
C. Soil chemical analysis		
Elements	**0–15 cm**	**Methods**
Organic carbon (%)	0.48	Walkley and Black method (Jackson, 1973)
$KMnO_4$oxidizable N (kg ha^{-1})	204.5	Modified Kjeldal's method, (Jackson,1958)
0.5 N $NaHCO_3$ extractable P (kg ha^{-1})	16.8	Olsen's method (Olsen,1954)
1 Neutral NH_4OAc-exracable K (kg ha^{-1})	232.6	Flame photometer method (Jackson, 1958)
pH (1:2.5 soil: water)	7.6	Glass electrode pH meter (Richards, 1954)
EC (dS m^{-1} at 25°C)	0.31	Conductivity bridge (Piper, 1950)

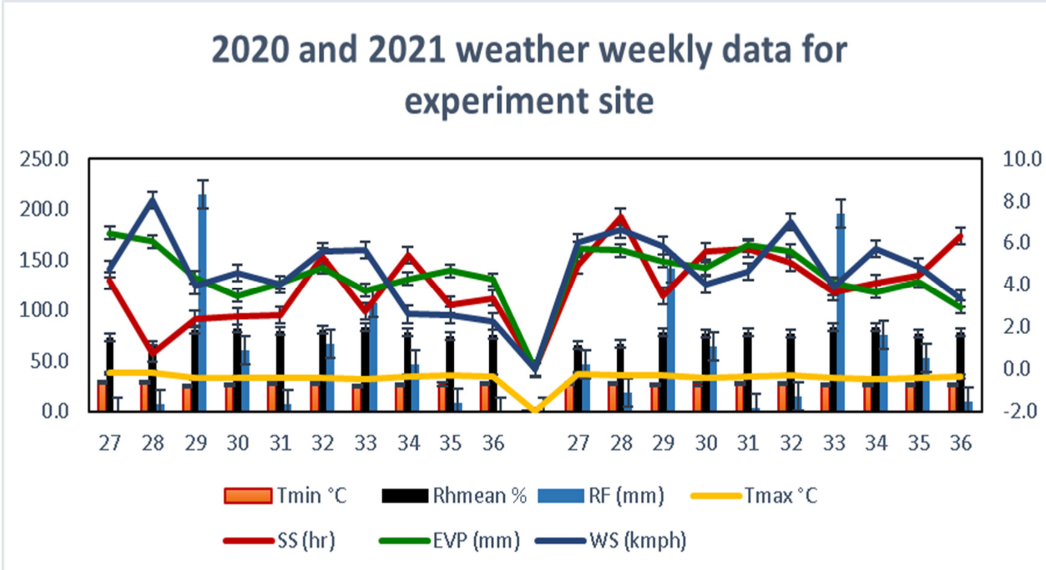

Fig. 1. Weather data of *kharif* season 2020-21 and 2021-22 of Min and maximum temperature, Rainfall (mm), Evaporation (mm), Sunshine hours; Relative humidity (%).

Grain Harvesting and Yield Measurement. Harvesting in the maize plots was done at physiological maturity. Ten seeds were collected at random from each plot weighed and dried in an oven and re-weighed to determine grain moisture content. The grain weight was then corrected for moisture content.

Grain Yield Y = FWP × DM × M × F

where Y = Grain yield in Kg·ha−1 at 12.5% moisture

FWP = Fresh weight of the net plot in kg, DM = Fraction of dry matter in sample (dry weight/fresh weight) in kg, M = Moisture factor (100/87.5) for 12.5% moisture, F =Conversion factor from g·net^{-1} plot kg·ha^{-1}

LER = Intercrop A yield/sole crop yield A + intercrop B yield/sole crop yield B

Statistical analysis. The data recorded for different parameters were analyzed with the help of the analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for split-plot design using SAS 9.1 software (SAS Institute, Cary, NC). The LSD test was used to separate the treatments' effect at 5% level of significance (*P=0.05*).

RESULTS

The study investigated the effects of different treatments on the growth and yield of intercropped pearl millet-cowpea and millet-cluster bean crops. Twelve treatments were tested, with the first six treatments being pearl millet-cowpea intercropping and the remaining six treatments being millet-clusterbean intercropping. The row ratio used was 1:1 and 2:2, and the first treatment was a conventional tillage system, while the remaining five treatments were under zero tillage with residues.

The results of this data set show the effects of twelve different treatments on the growth parameters and yield attributes. Treatment ZT2-PC (2:2) showed the highest LAI-30D (0.79a) and ZT4-PC (2:2) shown highest LAI-50 (6.03), and was 5.56 % higher over CT-PC (1:1). When looking at statistical significance (SED p=0.05), Treatment 8 had the highest SED for PH at 50DAS (1.20) and Treatment 11 had the highest SED for PH at 30DAS (1.98). The highest SED for Test Weight was found in Treatment 3 (0.4730) and Treatment 10 had the highest SED for seed pod-1 (0.25). Overall, Treatment 4 showed the best performance, with the highest LAI-30D, LAI-50D, PH at 50DAS, (Table 2) and test weight, and the second highest LAI-harvest and seed pod^{-1}. These results were in confirmation of (Maduwanthi *et al.,* 2019; Kumawat *et al.,* 2006; Rani *et al*., 2019; Patel *et al.,* 2010). This result is statistically significant and was found to have the lowest C.V. out of all the treatments.

ZT2-PC (2:2) Treatment had the best performance with a 1.86, while Treatment 7 had the worst performance with a 0.91. The standard error of difference was 0.0882 and the coefficient of variation was 2.25. With respect to SPAD value at 30 DAS, ZT2-PC (2:2) had the best performance with a 38.95, while in cluster eban ZT2-MCB (1:1) treatment show (42.32A) best performance. For Cowpea, ZT2-PC (2:2) and clusterbean (ZT4-PCB (2:2) recorded highest SPAD value at 50 DAS. PLER was best with treatment ZT2-PC (2:2) with 0.70, while Treatment ZT4-PCB (2:2) had the worst performance with a 0.22. and the coefficient of variation was 2.35 (Table 3).

Among the pearl millet-cowpea intercropping treatments (Treatments 1-6), Treatment 4 showed the highest DMA at both 30 and 50 days after planting (26.11B and 3.16B, respectively), as well as the highest CGR and RGR at 30 and 50 days after planting (Table 3). It was in agreement with (Adeniyan *et al*., 2011; Eskandari *et al*., 2009). Treatment 2 had the highest DMA at 50 days after planting (26.70A) and the highest NP and NB. Among the pearl millet-clusterbean intercropping treatments (Treatments 7-12), Treatment 9 had the highest DMA at 30 days after planting (2.653E) and Treatment 4 had the highest DMA at 50 days after planting (0.62B). Treatment 3 had the highest CGR at both 30 and 50 days after planting, while Treatment 10 had the highest RGR at both time points

The correlation matrix through a Pie diagram (Fig. 2) represents the correlation between the different parameter of growth, yield and yield attributing characters. The proportion and intensity of colour represent the correlation. Dark blue colour pies represent the higher positive correlates among them. Correlates show less and negative correlates as shown by blank and less fill pie section individually.

Principal component analysis results. This principal component analysis (PCA) of 12 treatments is showing the variance of the data in each component. The first component (Comp 1) has the highest eigenvalue at 17.93 and is responsible for 74.72% of the variance in the data (Table 4, Fig. 4). The second component (Comp 2) has an eigenvalue of 2.860 and is responsible for 11.94% of the variance. This pattern continues for all of the components up to Comp 11, which has an eigenvalue of 0.0057 and is responsible for 0.023% of the variance.

The principal component analysis (PCA) result through a biplot (Fig. 4) represent the proportion characters contributes to the final yield and output. Here the dimension on right side represents the group of variables that tend to be positively correlated with each other and dimension on left side represent negatively correlated component of the total system studied (Fig. 4).

The cumulative percentage of variance is the sum of the percentages for each component, so Comp 1 is 74.72%, Comp 2 is 86.67%, Comp 3 is 90.67%, and so on. By understanding the eigenvalues and cumulative percentages of variance, you can gain insight into how much each component contributes to the overall variance of the data and how important each component is in explaining the variance. In this case, Comp 1 has the highest eigenvalue and is responsible for the most variance, which indicates that it is the most important component in explaining the variance in the data.

Table 2: Effect of Planting ratio, residue intensity and tillage configuration on yield attributing characteristics.

Treatment	LAI-30D	LAI-50 DAS	PH at 30DAS	PH at 50	NP	NB
CT-PC(1:1)	0.68e	3.92e	23.51gh	67.32e	9.29h	4.05f
CT-PC (2:2)	0.71d	4.26d	25.01g	70.99d	12.18e	5.21c
ZT2-PC (1:1)	0.73c	4.37c	29.63e	84.46a	15.8a	4.10f
ZT2-PC (2:2)	0.79a	5.69b	23.62gh	67.91e	12.61d	3.11g
ZT4-PC (1:1)	0.73c	5.95a	22.23h	63.63f	14.76b	4.10f
ZT4-PC (2:2)	0.76b	6.03a	27.02f	77.74b	13.58c	4.90d
CT-PCB (1:1)	0.16h	1.61fg	67.42d	73.97c	7.36k	4.50e
CT-PCB (2:2)	0.18g	1.39h	74.39b	76.76b	9.06hi	5.97a
ZT2-MCB (1:1)	0.21f	1.69f	70.77c	78.44b	9.71g	5.26c
ZT2-PCB (2:2)	0.16h	1.21i	78.69a	82.75a	10.05f	5.73b
ZT4-PCB (1:1)	0.18g	1.44h	66.48d	69.58de	8.61j	5.36c
ZT4-PCB (2:2)	0.19g	1.59g	70.66c	78.53b	8.81ij	5.24c
SED (p=0.05)	0.007	0.046	1.98	1.20	0.162	0.242
C.V.	2.10	1.74	0.77	2.09	2.64	3.14
Different alphabet indicates statistically significant at 0.05 % level from student t test						

Table 3: Effect of Planting ratio, residue intensity and tillage configuration on yield attributing characteristics.

Treatment	Total LER	PLER	SPAD 30	SPAD at 50	WUE	System WUE	TNP^{-1}
Cowpea							
CT-PC(1:1)	1.03G	0.4G	33.49F	38.85D	0.99E	2.32G	0.50C
CT-PC (2:2)	1.32C	0.71C	33.89F	35.63G	1.41C	2.92D	0.60B
ZT2-PC (1:1)	1.267D	0.55E	36.63E	36.83FG	1.10D	2.87D	0.62B
ZT2-PC (2:2)	1.86A	0.90A	38.95CD	38.37DE	1.93A	4.14A	0.70A
ZT4-PC (1:1)	1.17EF	0.51F	41.41AB	39.01D	1.02E	2.74E	0.53C
ZT4-PC (2:2)	1.58B	0.82B	40.35BC	41.16C	1.73B	3.59B	0.66B
Cluster bean							
CT-PCB (1:1)	0.91H	0.36J	37.92E	37.27EF	0.47H	1.83I	0.26D
CT-PCB (2:2)	1.21E	0.61D	40.59B	41.48BC	0.78F	2.29GH	0.21D
ZT2-MCB (1:1)	1.22DE	0.51F	40.77AB	42.17ABC	0.76F	2.56F	0.25D
ZT2-PCB (2:2)	1.36C	0.42H	42.32A	43.15A	0.73F	3.07C	0.28D
ZT4-PCB (1:1)	0.93H	0.21K	36.47E	38.06DEF	0.50H	2.21H	0.26D
ZT4-PCB (2:2)	1.15F	0.40I	42.28A	42.61AB	0.67G	2.47F	0.22D
SED (p=0.05)	0.0882	0.0104	0.76	0.63	0.507	0.047	0.0263
C.v.	2.25	2.35	2.42	1.96	2.96	2.10	8.16
Different alphabet indicate statistically significant at 0.05 % level from student t test							

Table 4: Eigen value, and variance of component under Principal component analysis.

Component	Eigen value	% of total variance	Cumulative percentage of variance
Comp 1	17.93	74.73	74.73
Comp 2	2.87	11.95	86.68
Comp 3	0.96	4	90.68
Comp 4	0.92	3.84	94.52
Comp 5	0.49	2.04	96.56
Comp 6	0.41	1.71	98.27
Comp 7	0.19	0.8	99.07
Comp 8	0.18	0.73	99.81
Comp 9	0.03	0.13	99.93
Comp 10	0.03	0.64	99.96
Comp 11	0.01	0.04	99.98
Comp 12	0.01	0.02	100

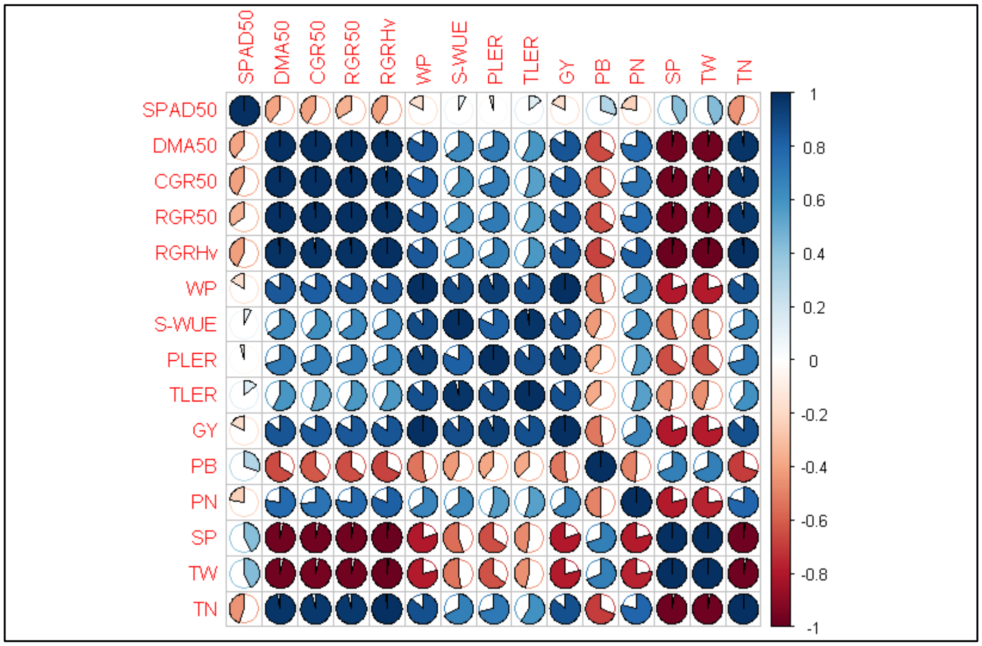

Fig. 2. Correlation matrix between different parameters of cowpea and cluster bean shown by proportionate relationships among the growth and yield attributes. GY: Grain yield, PB: Branches plant-1, SP: Seed Pod-1, TN: Total Nitrogen plant-1 (g), TW: Test weight, PLER: Partial LER, WP: Water productivity.

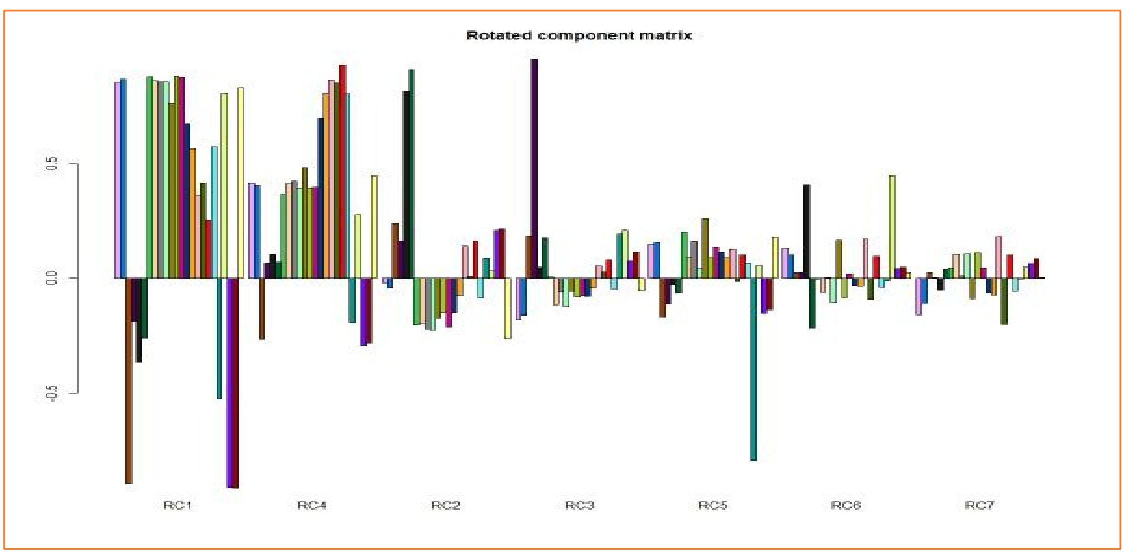

Fig. 3. Rotated component matrix of the Variables under experiments. Here each bar of different colour represent the individual parameter and size of bar represent the contribution of the parameters in overall performance of the studied. RC represent the grouping of the treatment parameters based on their performance.

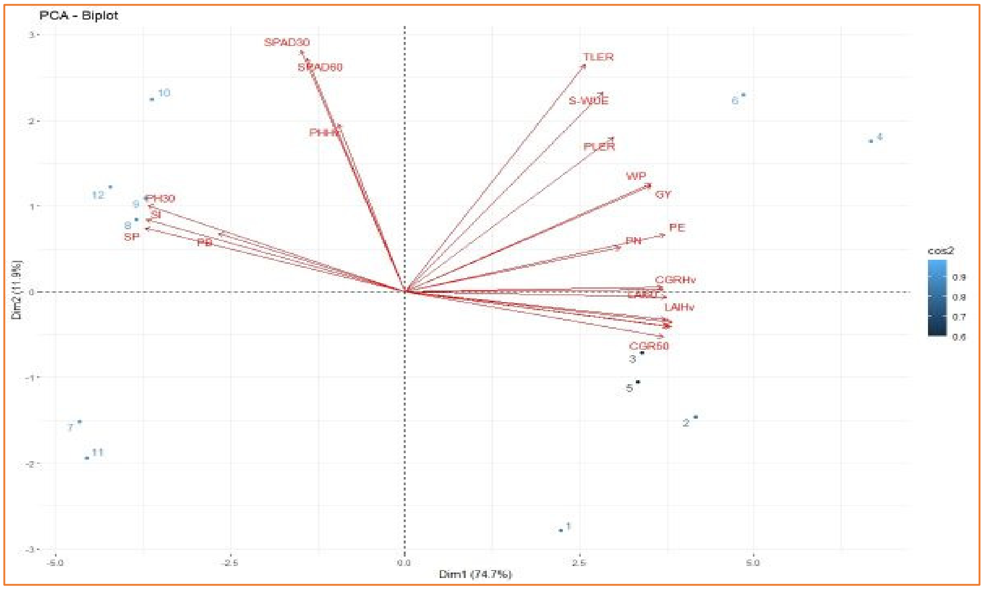

Fig. 4. PCA Biplot for variables of growth and physiological yield of cowpea and cluster bean.

DISCUSSION

Intensification of crop productivity through rotation and intercropping may enhance the productivity and yield stability in farmers' fields (Lithourgidis *et al*., 2011). Reduced evapotranspiration of the component crops resulting in better water use efficiency (Zhang *et al.,* 2018). High LER could perhaps be attributed to the fact of better utilisation of water and radiation by the intercropped stands. These results are in agreement with a study on productivity of maize and cowpeas under intercrop systems (Takim *et al.,* 2012). This is attributed better performance of intercrops to improved water and radiation use compared to sole crops. the modification of the light environment by the plant canopy affected positively the water relations of the intercropped plants by increasing the water use efficiency which would result in increased yields particularly benefiting farmers who live in the arid and semi-arid areas. Yield reduction under intercropping is associated with competition by component crops for nutrients, light and moisture. Yield reductions are more pronounced for cowpea than for the cereal crop, and this could be attributed to lack of belowground niche differentiation in root distribution and mutual shading. Biological fixation by legumes and intensification with cereals aided the nutrients to soil, improve fertility, biological activity and increase yield of component crops in complementary association (Ladha *et al.,* 2022).

SUMMARY

Agriculture plays a crucial role in global food security but faces challenges such as climate change, water scarcity, and soil degradation, which can lead to low crop yields and exacerbate poverty and food insecurity. To address these challenges and improve sustainable food security, efficient technologies for intensifying crop production in a sustainable manner are needed. This study investigated the effects of different tillage configurations, residue retention levels, and row ratios on the growth, yield, and economic benefits of intercropped pearl millet-cowpea and millet-cluster bean crops. The results showed that intercropping led to reduced evapotranspiration and better water use efficiency. High land equivalent ratio (LER) indicated better utilization of water and radiation by the intercropped stands. Yield reductions were attributed to competition for nutrients, light, and moisture, with cowpea being more affected than the cereal crop. Treatment 4, with zero tillage and 60% residue retention, showed the best performance in terms of growth parameters and yield attributes. These findings suggest that intercropping can improve water and radiation use efficiency, but careful management is needed to minimize competition and maximize yield benefits.

Conflict of Interest. None.

REFERENCES

Adeniyan, O. N. Ayoola, O. T., Ogunleti, D. O. (2011). Evaluation of cowpea cultivars under maize and maize-cassava based intercropping systems. *Afr. J. Plant Sci., 5*, 570–574.

Bouyoucos, C. J. (1951). Hydrometer method for making particle size analysis of soil. *Agronomy Journal 54*, 464–465.

Choudhary, M., Rana, K. S., Bana, R. S., Parihar, C. M. and Kantwa, S. R. (2021). Conservation agriculture practices and sulphur fertilization effects on productivity and resource-use efficiency of rainfed mustard (*Brassica juncea*). *The Indian Journal of Agricultural Sciences.*

Eskandari, H. and Ghanbari, A. (2009). Intercropping of Maize and Cowpea as Whole—Crop Forage: Effect of Different Planting Pattern on Total Dry Matter Production and Maize Forage Quality. *Notulae Botanicae Horti Agrobotanicae Cluj Napoca, 37*, 152-155

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S. and Johnston, M. (2011). Solutions for a cultivated planet. *Nature 478,* 337–342.

Fonteyne, S., Singh, R. G., Govaerts, B. and Verhulst, N. (2020). Rotation, Mulch and Zero Tillage Reduce Weeds in a Long-Term Conservation Agriculture Trial. *Agronomy, 10*, 962.

Garnett, T., Appleby, M. C., Balmford, A., Bateman, I. J., Benton, T. G. and Bloomer, P. (2013). Sustainable intensification in agriculture: premises and policies. *Science 341*, 33–34. doi: 10.1126/science.1234485

Gathala, M. K., Timsina, J., Islam, M. S., Rahman, M. M., Hossain, M. I., Harun-Ar-Rashid, M. and McDonald, A. (2015). Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice–maize systems: Evidence from Bangladesh. *Field Crops Research*, *172*, 85-98.

Gupta, R. K., Hans, H., Kalia, A., Kang, J. S., Kaur, J., Sraw, P. K., Singh, A., Alataway, A., Dewidar, A. Z. and Mattar, M. A. (2022). Long-Term Impact of Different Straw Management Practices on Carbon Fractions and Biological Properties under Rice–Wheat System. *Agriculture*.

Jackson, M. L. (1958). Soil chemical analysis, Asian Publication House, New Delhi, pp. 173–195.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall Inc., Englewood, Cliffs, U.S.A., pp. 159–174.

Khan, Z. R., Midega, C. A. O., Hassanali, A., Pickett, J. A. and Wadhams, L. J. (2007). Assessment of different legumes for the control of *Striga hermonthica* in maize and sorghum. *Crop Sci., 47*, 730–736.

Klik, A. and Rosner, J. (2020). Long-term experience with conservation tillage practices in Austria: Impacts on soil erosion processes. *Soil and Tillage Research*, *203*, 104669.

Kumawat, P. D., Yadav, G. L., Singh, M. and Jat, B. L. (2006). Effect of varieties and fertilizer levels on yield attributes and yield of cluster bean. *Agric. Sci. Digest., 26*(1), 63-64.

Ladha, J. K., Peoples, M. B., Reddy, P. M., Biswas, J. C., Bennett, A., Jat, M. L. and Krupnik, T. J. (2022). Biological nitrogen fixation and prospects for ecological intensification in cereal-based cropping systems. *Field Crops Research*, *283*, 108541.

Lejissa, L. T., Wakjira, F. S. and Tanga, A. A. (2022). Effects of Conservation Agriculture and Conventional Tillage on the Soil Physicochemical Properties and Household Income in Southern Ethiopia. *International Journal of Agronomy*.

Lithourgidis, A. S., Dordas, C. A., Damalas, C. A. and Vlachostergios, D. (2011). Annual intercrops: an alternative pathway for sustainable agriculture. *Australian journal of crop science, 5*(4), 396-410.

Maduwanthi, A. K. M. R. B. and Karunarathna, B. (2019). Biological and economic benefit of okra (*Abelmoschus esculentus* L.) cowpea (*Vigna unguiculata* L. Walp) intercropping in sandy Regosol. *Middle East Journal of Agriculture Research*, *8*(1), 28-34.

Mupangwa, W., Thierfelder, C. and Ngwira, A. (2017). Fertilization strategies in conservation agriculture systems with maize–legume cover crop rotations in Southern Africa. *Experimental Agriculture, 53*(2), 288-307.

Olsen, S. R., Cole, C. L., Watanabe, F. S. and Dean, L. A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular No. 939, Washington, pp. 72–75.

Patel, C. S., Patel, J. B., Suthar, J. V. and Patel, P. M. (2010). Effect of integrated nutrient management on cluster bean seed production. *International Journal of Agricultural Sciences, 6*(1): 206-208.

Piper, C. S. (1950). Soil and plant analysis. The University of Adelaide, Australia: 286–287.

Piper, C. S. (1966). Soil and Plant Analysis. Hans Publisher, Bombay.

Rana, K. S., Choudhary, A. K., Sepat, S., Bana, R. S., Dass, A. (2014) Methodological and Analytical Agronomy. [ISBN: 978–93–83168–07–1]. Post Graduate School, IARI, New Delhi–110 012, India. pp 276.

Pretty, J. and Bharucha, Z. P. (2014). Sustainable intensification in agricultural systems. *Ann. Bot. 114,* 1571–1596.

Rani, K., Sharma, P. K., Kumar, S., Wati, L., Kumar, R., Gurjar, D. S. and Kumar, D. (2019). Legumes for Sustainable Soil and Crop Management. *Sustainable Management of Soil and Environment*.

Richards, L. A. (1954). Diagnosis and improvement of saline alkaline soils. In USDA Handbook No. 60, Washington, pp. 111–112.

Smith, A., Snapp, S., Dimes, J., Gwenambira, C. and Chikowo, R. (2016). Doubled-up legume rotations improve soil fertility and maintain productivity under variable conditions in maize-based cropping systems in Malawi. *Agricultural Systems*, *145*, 139-149.

Takim, F. O. (2012). Advantages of maize-cowpea intercropping over sole cropping through competition indices. *Journal of Agriculture and Biodiversity Research, 1*(4), 53-59.

Thierfelder, C., Cheesman, S. and Rusinamhodzi, L. (2012). A comparative analysis of conservation agriculture systems: Benefits and challenges of rotations and intercropping in Zimbabwe. *Field crops research*, *137*, 237-250.

Tilman, D., Balzer, C., Hill, J. and Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad. Sci. U.S.A. 108,* 20260–20264.

Tiwari, R., Yadav, R. S. and Kumawat, A. (2015). Evaluation of pearlmillet (*Pennisetum glaucum*)and clusterbean (*Cyamopsis tetragonoloba* L.) intercropping system under arid western plain zone in India. *Indian Journal of Agricultural Research*, *49*(3), 229-234.

Vanlauwe, B., Coyne, D., Gockowski, J., Hauser, S., Huising, J. and Masso, C. (2014). Sustainable intensification and the African smallholder farmer. *Curr. Opin. Env. Sust., 8*, 15–22.

Yadav, B.L., Patel, B., Ali, S. and Yadav, S.K. (2015). Intercropping of legumes and oil seed crop in summer pearlmillet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz]. *Legume Research, 38*, 503-508.

Zhang, Y., Wang, J., Gong, S., Xu, D., Sui, J., Wu, Z. and Mo, Y. (2018). Effects of film mulching on evapotranspiration, yield and water use efficiency of a maize field with drip irrigation in Northeastern China. *Agricultural Water Management, 205,* 90-99.

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