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Statistical analysis of field data using correlation and regression analysis for cluster bean crop under conservation agriculture

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Abstract
A field experiment was conducted in New Delhi, India, 2021, under rainfed semi-arid conditions to evaluate the impact of three tillage practices, and six levels of sulphur on productivity and soil health. The study focused on correlation of different yield and yield attributes with soil biological properties. Current study experiment made of three tillage practices like: ZT+R, ZT+R and CT while six level of sulphur *viz,* S1: Control S2: RDS 30 kg/ha S, S3: Foliar application of ATS 5m/L once S4: Foliar application of ATS 10m/L once S5: Foliar application of ATS 5m/L twice and S5: Foliar application of ATS 10m/L twice. Among Tillage practices ZT+R showing significantly higher yield and yield attributes characters as well as soil enzymes while it was also interrelated with CT. Sulphur management also significantly gave higher results with soil application of sulphur 30kg/ha that is at par with foliar application of ATS 10m/L twice. Among the foliar application of ATS, foliar applied ATS 10m/L twice recorded significantly higher yield and soil character compared to remaining foliar application of ATS. The study also revealed that yield attributes are positively correlated with pod yield and final output. Regression analysis showed a negative trend of these parameters cluster per plant and number of pods per cluster. Hence, the ZT+R showed significant improvement in yield and soil biological properties with soil application of 30 Kg/ha S as well as foliar fertilization of ATS twice.

Keywords: Ammonium thiosulphate, conservation agriculture, correlation, foliar fertilization

Introduction
Cluster bean (*Cyamopsis tetragonoloba* L.) is predominantly cultivated in arid and semi-arid regions of India, Pakistan, South Africa, and the United States (Ashraf and Iram, 2005; Punia *et al.*, 2009) [3, 12]. The pods of cluster beans find application as a vegetable, while the extraction of galactomannans from guar, known as guar gum, adds to its industrial significance (Sabahelkheir *et al.,* 2012) [15]. The grain composition of cluster bean includes germ (41-46%), endosperm (34-43%), and hull (13-18%) (Srivastava *et al.,* 2011) [21]. Beyond its utility as a food source, cluster bean is employed as a green manure crop in various regions. The husk derived from cluster bean is utilized as cattle feed due to its rich protein content (Rai and Dharmatti, 2013) [13]. Notably, cluster bean emerges as a valuable nutritional resource, containing fats, proteins, phosphorus, calcium, and mineral salts (Kumar and Rodge, 2012) [8]. As a leguminous crop, cluster bean plays a crucial role in nitrogen fixation, contributing to enhanced soil fertility (Rai and Dharmatti, 2013) [13].
To meet the escalating demand for food, sustaining agricultural production requires fertile soil and optimal crop management practices. Transitioning from conventional tillage to conservation agriculture (CA) is often recognized as a superior approach to improve nutrient status, enhance soil health, and boost crop productivity (Saikia *et al.*, 2020) [17]. The core principles of CA encompass: (i) minimizing soil disturbance, (ii) maintaining maximum soil cover throughout the year through practices like crop residue retention or cover crops, and (iii) implementing diversified crop rotations to achieve heightened productivity (Busari *et al.*, 2015) [4].

This approach promotes crop growth and productivity soil health and quality by elevating soil organic carbon (SOC) levels and enhancing soil aggregation. (Lal, 2007; Dalal *et al.*, 2011; Somasundaram *et al.*, 2017, 2019) [10, 5, 19, 20]. As a result, CA contributes to improved infiltration and reduced soil erosion losses (Govaerts *et al.*, 2009) [6].

However, scant information is available on the supplementation of other mineral nutrients, including sulfur (S), a secondary macronutrient. Sulfur is recognized not only for its pivotal role in plant growth and development (Kopriva *et al.*, 2019) [7] but also for its positive impact on crop productivity (Tiwari and Gupta, 2006; Ali *et al.*, 2013) [22, 1] and quality (Ankit *et al.*, 2021) [2]. Furthermore, sulfur deficiency has been identified in 29% of soil samples and is considered potentially deficient in 40% of samples across India (Sahrawat *et al.*, 2007; Shukla *et al.*, 2021) [16, 18]. This deficiency can be attributed to the adoption of high-yielding crop varieties in multiple cropping systems, continuous use of sulfur-devoid high-analysis fertilizers such as diammonium phosphate and urea, as well as the inadvertent application of insecticides and fungicides for crop production, leading to soil exhaustion in terms of sulfur content (Prasad, 2005; Rakesh *et al.*, 2020) [11, 14]. Therefore, the study was designed to investigate the effect of tillage practices with sulfur management on the yield and soil health of cluster bean crops.

Materials and Methods

The experiment took place during the summer seasons of 2021 at the Research Farm within the Division of Agronomy at ICAR-IARI, New Delhi. Geographically, the experimental site is situated in the subtropical zone of the Trans-Gangetic plains, on the left bank of the largest tributary of the Ganges, the Yamuna River. Positioned at latitude of 28°38' N, 77°11' E, and an altitude of 228.6 meters above mean sea level, this location experiences a sub-tropical and semi-arid climate. The Union Territory of Delhi, falling within the "Trans-Gangetic plains" zone, is characterized by hot and dry summers and cold winters. The peak of summer, in May and June, witnesses the highest temperatures ranging between 41 °C and 46 °C, followed by a gradual decrease in temperature from September onward. January marks the coldest period of the year, with minimum temperatures ranging from 5 °C to 7 °C. The soil type of Research Farm in IARI (New Delhi) is Typic Haplustept (Saha *et al.*, 2010) [25]. The experiment was laid out in a split-plot design (SPD). The sub-plot treatments were randomized in different main plots using the random number table of Fisher and Yates (1963) and replicated thrice. The layout plan of the experimental field with information regarding dimensions of the main plot and subplot etc.

Table 1: The sub-plot treatments were randomized in different main plots using the random number

Treatments		Notation used
Main plot	Conventional tillage	CT
	Zero tillage without residue	ZT-R
	Zero tillage with residue	ZT+R
Subplot plot	Control	S_1
	RDS @30 Kg/ha	S_2
	Foliar application of ATS at 5 ml/L once	S_3
	Foliar application of ATS at 10 ml/L once	S_4
	Foliar application of ATS at 5 ml/L twice	S_5
	Foliar application of ATS at 10 ml/L twice	S_6

Statical analysis: Data for twelve quantitative traits were collected from five randomly selected plants in each plot, and mean values were computed for subsequent statistical analysis. The data obtained from the current field experiment underwent statistical analysis, employing the F-test following the methodology outlined by Gomez and Gomez (1984). Post-hoc mean separation was conducted using Tukey's honestly significant difference test ($p<0.05$) through SAS 9.1 (SAS Institute, Cary, NC). The Tukey procedure was applied when the analysis of variance (ANOVA) yielded significant results.

Results and Discussion

Yield and Yield attributes

Yield and yield attributes significantly ($p<0.05$) affected by different tillage practices and sulphur management. Among the different tillage practices significantly higher yield and yield attributes found under ZT+R compare to ZT-R and CT but this was found on par with CT. This could be attributed to the positive impact of soil coverage facilitated by a 5 cm thick mulch layer of crop residue. This covering ensures a sufficient and well-balanced moisture supply, resulting in enhanced nutrient absorption, efficient assimilation and distribution of metabolites, as well as ample accumulation and translocation of photosynthates. Consequently, this has led to a noteworthy enhancement in yield attributing characters (Choudhary *et al.*, 2014, Sinha, 2015) [23, 24]. Similarly sulphur management proved significantly affected the yield and yield attributes. Among the S management RDS 30 Kg/ha S found significantly higher compared to remaining treatment but it was at par foliar application of ATS at 10 ml/L twice. Foliar feeding of sulfur through ammonium thiosulfate (ATS) significantly enhanced yield attributing characters such as cluster per plant and pods per cluster and pod yield over the control. This might be due to improved nutrient uptake, efficient partitioning of metabolites, adequate translocation and accumulation of photosynthates in the sink which later on get converted into reproductive phase.

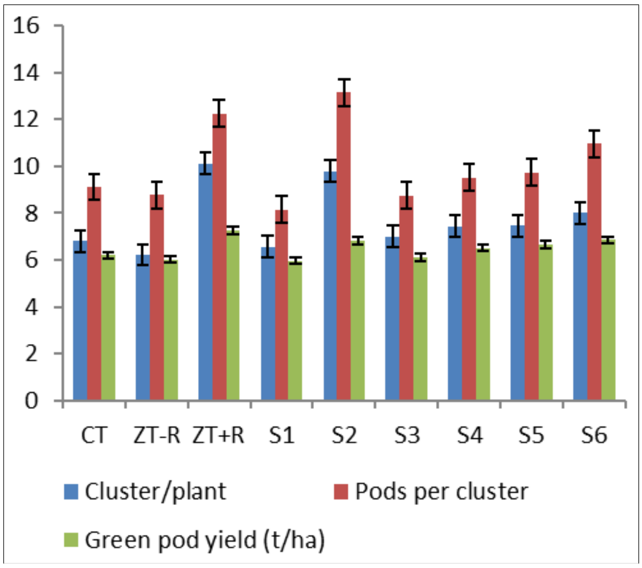

Fig 1: Yield and yield attributes affected by tillage practice and sulphur management

The various growth components and soil enzyme activities under examination may display correlations with each other, influencing the overall pod yield (Fig. 2). This association can be either positive or negative. The Karl Pearson's correlation coefficient (r) quantifies the strength of the correlation between two characteristics. A correlation coefficient closer to -1 or +1 suggests a high degree of linear relationship, while a value near zero indicates no linear relationship. In Fig-2, the inter-character correlations among pod yield (PY), cluster per plant, number of pods per cluster, pod yield per plant, soil microbial carbon, dehydrogenase activity (DHA), alkaline phosphatase (ALP), and aryl sulfatase (AS) are presented. The blue color represents the strongly significant relation between the variables, while the light blue color fill of the value represents the significant negative relationship among variables, with the nonsignificant relationships indicated by the cross sign.

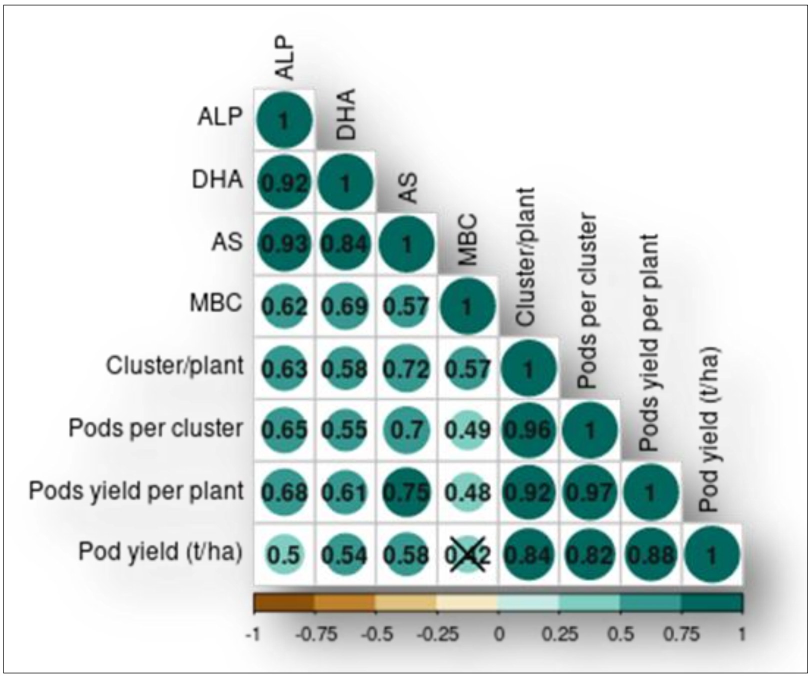

Fig 2: Corrplot describing Pearson's correlation (two-tailed t-test) between yield attributes and soil microbial activity influenced by tillage practices and sulphur management. Based on the guideline color below the heat map, green circles show a positive correlation at *p*≤0.05, and blank squares show no correlation. Darker colors and bigger circles indicate larger correlation coefficient.

The current investigation aimed to comprehend the impact of various permutations of tillage practices and sulfur management on pod yield (t/ha). Overall, pod yield served as the dependent variable influenced by growth and yield attributing characteristics. Regression analysis revealed a robust correlation. In the moderator correlation (Figure 2), an expansion in the area was observed with the cluster per plant (R^2 = 0.707), (Figure 2A), and pod yield per plant (R^2 = 0.777), (Figure 2B).

Soil biological properties significantly affected the productivity of cluster beans, indicating their importance in determining the Soil Biological Index. Principal Component Analysis (PCA) involving all soil biological properties and yield attributes demonstrated that 73.6% of the variance was explained in the PCA of 7 variables, and 4 Principal Components (PCs) were extracted with eigenvalues > 1. Pod yield (PY), cluster per plant, number of pods per cluster, and pod yield per plant contributed to 73.6% of the total variance, being highly weighted variables in PC1. PC2 accounted for 14.4% of the total variance and included soil microbial carbon, dehydrogenase activity (DHA), alkaline phosphatase (ALP), and aryl sulfatase (AS).

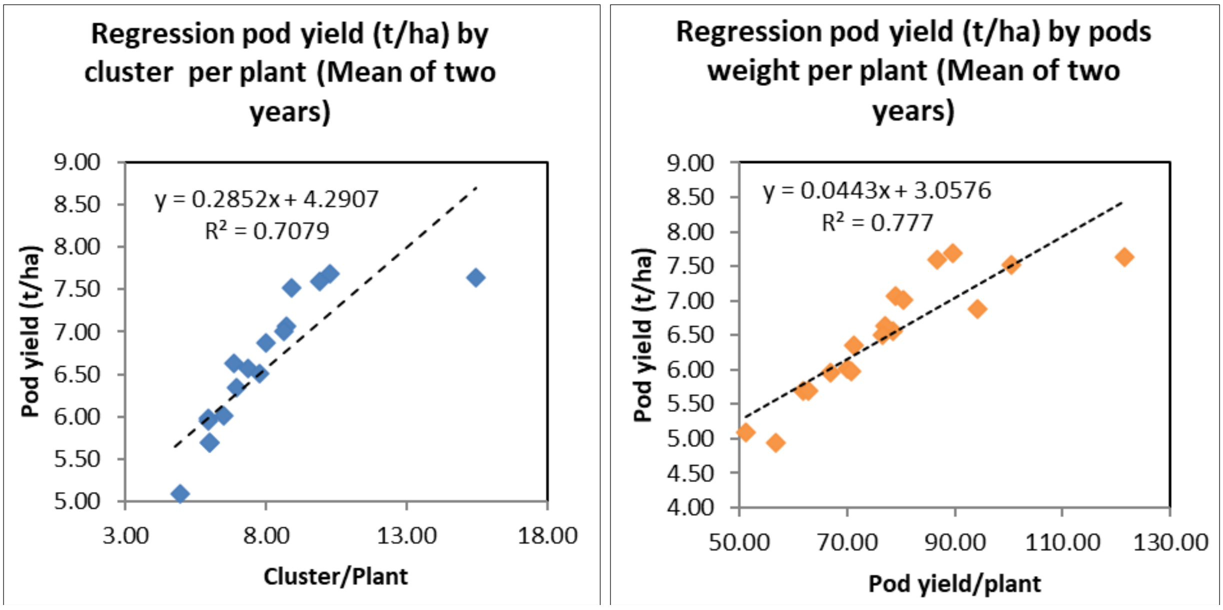

Fig 3: Regression relationship with R2 value in (A) pod yield (t/ha) and cluster per plant and (B) pod yield (t/ha) and pod yield per plant (g)

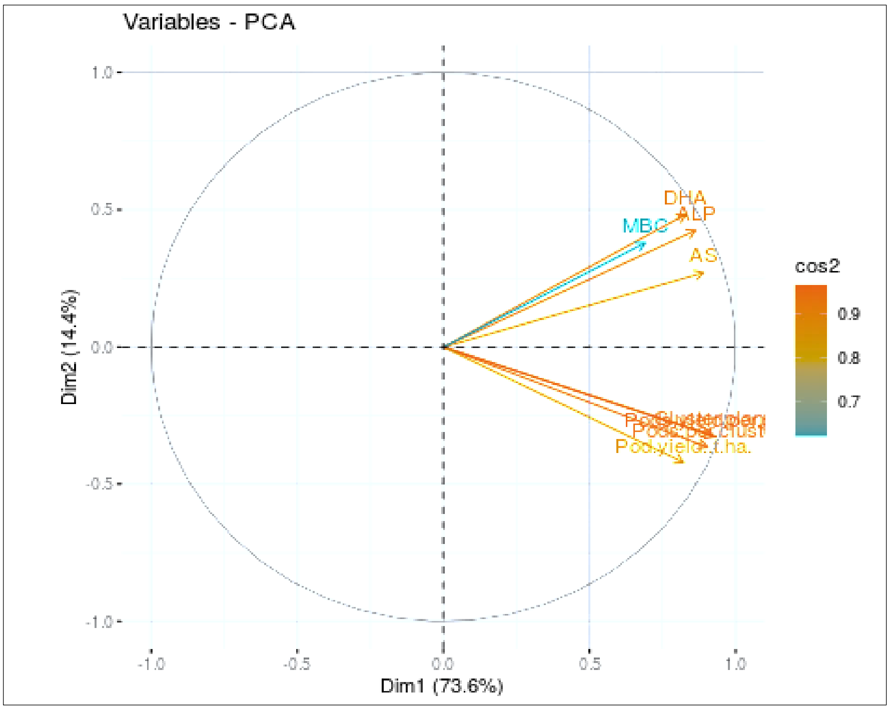

Fig 4: Graphic display biplot for soil biological character and yield attributes as influenced by tillage practices and sulphur management practices. Pod yield (PY), cluster per plant, number of pods per cluster, pod yield per plant, soil microbial carbon, dehydrogenase activity (DHA), alkaline phosphatase (ALP) and aryl sulpahate (AS)

Conclusions

Based on experimentation, it was determined that tillage practices significantly improved growth, yield attributes, yield, and soil attributes. Similarly, sulfur management in soil, as well as foliar fertilization, yielded significant results in terms of crop attributes (growth and yield). Based on the research findings, it can be concluded that Zero Tillage with Residue retention (ZT+R) resulted in higher yields and improved soil quality when combined with foliar fertilization of 10 ml/L ammonium thiosulfate (ATS) applied twice.

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