AATCC Review

25 October 2024: Received
28 December 2024: Revised
23 January 2025: Accepted
28 January 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Influence of Intercropping and Planting Techniques on Sugarcane Yield and Nutrient Absorption in the North West Alluvial Plains of Bihar

Ajeet Kumar[1]*, S. K Sinha[2], Sanjay Kumar Singh[3], Lalita Rana[4], A. K. Singh[5], Kumari Sunita[6], Amrendra Kumar[7], Harendra Singh[7] and Sudhir Paswan[8]

[1]Department of Microbiology, College of Basic Sciences and Humanities (CBS&H), Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India
[2]Department of Soil Science, Regional Research Station, Madhopur, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India
[3]Department of Soil Science, Tirhut College of Agriculture, Muzaffarpur, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India
[4]Department of Agronomy, Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India
[5]Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India
[6]Department of Food and Nutrition, College of Community Science, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India
[7]Department of Agronomy, Tirhut College of Agriculture, Muzaffarpur, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India
[8]Department of Statistics and Computer Applications, CBS&H, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur)-848125, Bihar, India

ABSTRACT

Adopting a double-row planting system for sugarcane(Saccharumofficinarum L.) cultivation has emerged as a promising approach to boost both productivity and yield. Additionally, integrating intercropping within sugarcane fields further enhances growth and productivity. To explore the potential benefits of these practices, a study was conducted at the Regional Research Station in Madhopur, West Champaran, during the 2019-2020 and 2020-2021 growing seasons. The experimental design was a randomized block, consisting of eight treatments with three replications each. The findings revealed that the sole PRS (60 x 60-120 cm) method produced a significantly higher yield compared to the conventional 90 cm furrow method. Among the different intercropping systems and planting methods, the highest cane yield (96.73 t ha^{-1}), maximum single cane weight (1079 g), greatest green top yield (14.69 t ha^{-1}), and trash yield (9.98 t ha^{-1}) were achieved by the PRS intercropped with gram (Cicer arietinum). Potato recorded the highest yield (20 t ha^{-1}) among the intercrops. The study also noted significant uptake of nitrogen and potassium, though phosphorus uptake was not significant. The highest uptake of nitrogen, phosphorus, and potassium occurred when PRS sugarcane was intercropped with vegetable pea (Pisum sativum).In conclusion, the paired row planting method for sugarcane proved more advantageous and profitable than the conventional 90 cm spacing method. The intercropping combination of sugarcane and pea in the paired row planting method (60 x 60-120 cm) was identified as the most lucrative, closely followed by the combination of sugarcane intercropped with gram.

Keywords: *Sugarcane, Nutrient, Intercrops, Potato, Pea, Rajmah, Lentil, and Coriander*

Introduction

Intercropping, the practice of cultivating two or more crops simultaneously in the same field increases the efficiency of resource utilization and crop yields [32], ultimately improving the fertility of agricultural lands [4], [12]. Compared to monocropping, this method commonly involves the co-cultivation of crops like soybeans and grasses. This combination is particularly beneficial, enhancing the interaction within the rhizosphere, improving the soil micro-ecology, and increasing the number of soil microorganisms and enzyme activities [40] [15], [33]. Sugarcane holds significant importance in many countries, as it serves as the primary raw material for sugar and ethanol production [5]. Sugarcane, as a primary source of sugar and biofuel, is extensively cultivated in tropical and subtropical regions [24]. India, with roughly 60% of its population involved in agriculture, is a country where agriculture plays a significant role. Sugarcane, among the various crops grown in the nation, is one of the most critical *Rabi* crops. The country's climate allows for sugarcane cultivation throughout the year. This versatile crop is utilized in the production of sugar, jaggery, khansari, molasses, and even paper [14], [4]. Sugarcane holds a critical position as one of the primary commercial crops. In India, it covers an expansive cultivation area of 5.04 million hectares, yielding an impressive 348.04 million tonnes of cane with an average productivity of 69 tonnes per hectare. Beyond its agricultural significance, sugarcane plays a vital role in bolstering the Indian economy.

*Corresponding Author: ***Ajeet Kumar***

DOI: https://doi.org/10.21276/AATCCReview.2025.13.01.144
© 2025 by the authors. The license of AATCC Review. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).

© 2025 AATCC Review. All Rights Reserved.

The sugar industry, with a staggering worth of 550 billion rupees, supports over 50 million farmers across the country, underscoring the sector's substantial socioeconomic impact. The demand for sugar is on the rise in India, where sugarcane serves as the principal cash crop in the state of Bihar. In the recent year, Bihar ranks 4thin terms of cultivation area, 5thin total cane production, and 12thin cane yield per hectare. Notably, Bihar boasts an average sugar recovery rate of 11.85%, among the highest in the country. This impressive performance is primarily due to the state's favorable agroecological conditions, which encourage greater sugar accumulation in the cane [23]. Additionally, sugarcane, being a C4 plant, is one of the most efficient plants, converting solar energy into sugar, enhancing its productivity and economic value. C4 plants are plants that use the C4 carbon fixation pathway to convert carbon dioxide (CO_2) into sugars during photosynthesis [34]. This adaptation to hot and dry environments enhances the efficiency of carbon fixation compared to the traditional C3 pathway used by most plants. In C4 plants, carbon fixation occurs in two stages and involves two distinct cell types: mesophyll cells and bundle sheath cells. Initially, in the mesophyll cells, carbon dioxide is fixed into a four-carbon compound (hence the term "C4") by the enzyme phosphoenolpyruvate carboxylase. This four-carbon compound is then transported to the bundle sheath cells. There, it releases carbon dioxide, which enters the Calvin cycle to produce sugars. This system allows the plant to efficiently capture and concentrate carbon dioxide, reducing photorespiration. As a result, the plant can maintain photosynthesis even under conditions of low atmospheric carbon dioxide, high light intensities, or high temperatures. Examples of C4 plants include sugarcane, corn (maize) and sorghum. These plants tend to be very efficient at photosynthesis and often grow faster than C3 plants, especially in hot, sunny environments.

Intercropping is a sustainable agricultural practice that optimizes time and space, leading to higher crop intensification [18]. Intercropping offers numerous benefits beyond diversification and improved labor distribution, such as maintaining soil fertility, suppressing weeds, and enhancing productivity and stability. It promotes efficient use of solar energy, moisture, and nutrients, resulting in greater overall productivity. The diversity in intercropping adds stability to the agricultural system by reducing the risk of single crop failure. Implementing intercropping strategies allows farmers to better exploit ecological processes, maximizing yield and sustainability. Many successful intercropping systems have demonstrated increased production on smaller landholdings, as monocropping often fails to meet economic needs. Intercropping enables the growth of two crops per year and can influence sugarcane yield and its components due to nutrient competition and environmental factors. This approach provides additional income alongside the sugarcane crop. With sugarcane planted at wider row spacing, the unused inter-row space during the early growth stage (about 120 days) can accommodate short-duration winter crops, increasing total yield, monetary returns, and resource utilization, thus meeting various farmers' needs. In sugarcane farming, intercropping with short-duration crops like potato, coriander, mung-bean, and lentil has proven to be more profitable compared to growing sugarcane as a sole crop [1]. This integrated approach enhances land productivity, improves nutrient cycling and boosts overall farm profitability. As land holdings shrink due to a growing population, the demand for food-cereals, pulses, oilseeds, vegetables, sugar, and more-continues to rise. With limited agricultural land, increasing crop production is challenging, so the focus has shifted to boosting productivity on existing land. Intercropping with sugarcane is an effective strategy.

Sugarcane, typically spaced 90 cm apart and occupying fields for a year, allows for the growth of intercrops between rows, making efficient use of land.The North West alluvial plains, with high rainfall and ideal conditions for sugarcane cultivation, are economically favorable for farmers due to the prevalence of sugarcane industries. Intercropping can maximize yield and income in this region, which has an average rainfall of 1350 mm. To meet the commercial demand for sugarcane, there is a need to increase its productivity. Understanding the impact of intercropping and various planting methods on sugarcane yield and nutrient uptake is crucial. Therefore, a study was initiated to explore these effects, aiming to provide valuable insights and practical recommendations for sugarcane growers in the North West alluvial plains of Bihar, helping them maximize sugarcane yield and profitability.

Material and Methods

Location of experimental site

During the *Rabi*season of 2019, this research was conducted at the experimental farm of Regional Research Station, Madhopur, West Champaran, falling under Agro-climatic zone-I of Bihar, and is positioned at North latitude 27° 03' 54" and East longitude 84° 20' 31".

Climatic requirements for sugarcane cultivation

Sugarcane, can thrive not only in tropical regions but also in subtropical ones such as northern India. During the months of vegetative growth, the plant requires total rainfall between 1100 and 1500 mm, followed by a dry spell for proper ripening. The growth of sugarcane is deeply influenced by temperature. It can survive in temperature range beyond 38°C, with the ideal germination temperature falling between 27° and 33°C. Temperature below 27°C can harm the cane, resulting in reduced tillering, while temperatures above 38°C can negatively impact sprouting. For various growth stages, the plant requires different optimal temperatures: 30°C for carbon assimilation and sugar synthesis, 30-35°C for sugar transport, 33.3-34.4°C for tillering, 36°C for root growth, and 33°C for shoot growth. Regarding relative humidity, sugarcane requires a high level (80-85%) during the grand growth phase. Warm weather and humidity above 40% promote vegetative growth, while a moderate humidity (45-65%), coupled with a limited water supply, benefits the ripening phase. Sugarcane also needs ample sunlight, with an ideal range of 7-9 hours per day. Frost is detrimental to its growth, as severe cold can inhibit bud sprouting in ratoons. When temperatures drop between -1°C and 2°C, the meristem tissues can die. High-velocity winds, exceeding 60 km/hr, can causing lodging and breakage.

Weather variables on experimental site

The average rainfall at experimental site ranged between 1050 mm - 1350 mm, which almost satisfies the irrigation needs for sugarcane cultivation. Temperature also plays a vital role in sugarcane development. Minimum temperatures recorded ranged from 12.95°C to 27.10°C, and maximum temperatures ranged between 18.32°C to 39.17°C. These temperature ranges were conducive to the crop's growth throughout the year. A relative humidity of 75-87% facilitated rapid cane elongation, while a moderate humidity of 45-65%, in conjunction with a limited water supply, was favourable for the ripening phase. Humidity above 40%, particularly between 42.33% and 54.70%, along with warm weather, promoted the vegetative growth [13]. Sugarcane, being a sun-loving plant, responds positively to high levels of incident radiation, leading to higher sugar yields. The experimental site have 7-9 hours of bright sunshine per day, which was beneficial for both the active growth and ripening stages of sugarcane, thus fostering higher

© *2025 AATCC Review.* All Rights Reserved.

production. In conclusion, despite the occasional erratic rainfall, the overall climatic conditions at the experimental site, with its optimal temperature, humidity, sunshine hours and irrigation, offer a favourable environment for sugarcane cultivation.

Experimental Design and Treatment details

The experiment utilized a Randomized Block Design with three replications. The total plot size was 8.0 m x 5.4 m, and the net plot size was 8.0 m x 4.8 m. The sugarcane variety CoP-16437 was used, alongside intercrops such as potato, rajmah, pea, lentil, gram, and coriander, all cultivated within the experimental field. The treatment details are as follows:T_1: Sole sugarcane - 90 cm row Spacing; T_2: Sole paired row sugarcane (60 × 60 cm – 120cm); T_3: Paired row sugarcane (PRS) + Potato; T_4: Paired row sugarcane (PRS) + Rajmah; T_5: Paired row sugarcane (PRS) + Pea; T_6: Paired row sugarcane (PRS) + Lentil; T_7: Paired row sugarcane (PRS) + Gram; T_8: Paired row sugarcane (PRS) + Coriander.Sugarcane was planted using a paired row system with 60 cm x 60 cm - 120 cm spacing. Three-budded setts were placed in rows at a depth of 4-5 cm. The conventional planting method used 90 cm spacing, involving furrow digging at a depth of 15 cm for sett placement. Setts in both methods were treated with carbendazim/bavistin. Six lines of sugarcane were maintained in both systems. Intercrops were sown in the 120 cm gap between paired rows and on both sides of the plots.For Rajmah, Lentil, and Gram, dibbling was performed at 30 cm row spacing, with two rows within the 90 cm gap and an additional row on each side, totaling eight rows per plot. Potato and vegetable pea seeds were planted at 20 x 10 cm spacing, maintaining six rows within the paired row gaps and one row on each side, also totaling eight rows per plot. For Rajmah, Lentil, and Gram, seeds were lined at 30 x 10 cm spacing, with four lines within the paired row gaps and two rows on both sides. Coriander seeds were sown at 30 x 20 cm spacing, following the same arrangement of four lines within the paired row gaps and two rows on both sides.

Fertilizer application

The field experiment applied the recommended fertilizer dose for sugarcane: 150 kg N ha^{-1}, 85 kg P_2O_5 ha^{-1}, and 60 kg K_2O ha^{-1}. At planting, 10% of the nitrogen and the full doses of P_2O_5 and K_2O were applied via placement method just before planting the sugarcane setts [19]. The remaining nitrogen was split into three doses (40%, 10%, and 40%) administered at six-week intervals.For intercrops, the following fertilizer recommendations were used:Coriander: 60:40:30 kg ha^{-1} at sowing; Pea, lentil, and gram: 20:45:20 kg ha^{-1} as a basal application; Rajmah: 100:50:30 kg ha^{-1};Potato: 150:90:100 kg ha^{-1}; Phosphorus and potassium (100% of P_2O_5 and K_2O) were applied as basal applications, with nitrogen split into three doses.Intercultural operations and plant protection measures were conducted as necessary. Intercrops were harvested, uprooted, cleaned, and their fresh yield per net plot was recorded and converted to a per-hectare basis. At maturity, sugarcane was harvested, with green tops and dry leaves separated from the millable cane. Observations during harvest included recording the weight of millable canes per net plot using a platform balance, which was then converted to per-hectare yield. The weight of green tops and trash per net plot was recorded and converted to a per-hectare basis.

Soil analysis

The preliminary and post-harvest soil samples were gathered to analyze various soil properties. The soil pH was measured utilizing a glass electrode pH meter (Model-Systronics-36), adhering to a soil-water suspension ratio of 1:2.5, a method recommended by Jackson (1973). The electrical conductivity (EC) of the soil was gauged using an EC meter (HANNA-HI2300) at a soil-to-water ratio of 1:2.5. Organic carbon content in the samples was assessed by employing Walkley and Black's wet oxidation method [37].

The quantities of available nitrogen, phosphorus, and potassium were determined according to the Alkaline potassium permanganate method [35], the Ascorbic acid method [38] and the Flame photometry method [9] respectively. The method articulated by Berger and Trough [2] was used to gauge hot water soluble B in the soil. Lastly, the Diethylenetriaminepenta acetic acid (DTPA)-extractable zinc level was estimated following the procedure established by Lindsay and Norvell [23].

Plant analysis

The canes sampled for dry matter assessment at harvest were used for chemical analysis.

The dried samples were pulverized into a fine powder using 100 mesh sieves, and ten grams of this powder were set aside in labeled brown paper bags for future evaluation. Nitrogen content was determined using the Microkjeldahl method, phosphorus using the molybdovandate phosphoric acid method and potassium using the flame photometric method. The uptake of nitrogen, phosphorus, and potassium (kg ha^{-1}) was calculated by multiplying the nutrient percentage in the cane by the corresponding dry yields of each element. Data from the experiment were analyzed using the method by Panse and Sukhatme [27].

Results and Discussion

Initial soil analysis report of the experimental site

The initial analysis of the surface soil (0-15 cm) of experimental field provided several significant insights about its properties. The texture of the soil was observed sandy loam to loam, which promises good drainage. However, these soil types may present challenges regarding nutrient retention and water availability [17], which can impact the growth and development of crops. The soil pH was measured 8.28, indicating an alkaline nature. Alkaline soils can restrict the availability of certain nutrients, particularly iron, zinc and manganese. Care should be taken to manage this pH level, as it might potentially influence the effectiveness of fertilizers and the overall nutrient management strategy. The electrical conductivity of the soil was 0.73 dS m^{-1}, which suggests a relatively low salt concentration in the soil. This is favourable for most of the crops, as high EC can lead to issues like salt stress [26]. The organic carbon of the soil was found 0.61%, pointing to a moderate level of organic matter. Organic matter plays a crucial role in improving soil fertility by enhancing nutrient and moisture retention.The available nitrogen content was 265 $kgha^{-1}$, which is a crucial nutrient for plant growth, playing a key role in protein synthesis and photosynthesis. P_2O_5 and K_2O availability were noted 22 $kgha^{-1}$ and 172 $kgha^{-1}$, respectively. Both are essential macronutrients for crops and contribute significantly to their overall growth and yield.The soil contained 0.65 ppm of available zinc, which falls within the medium range. Zinc is a vital micronutrient which aids in enzymatic activities and protein synthesis. The available boron was measured 0.31 ppm. It is essential for cell wall formation and transportation of sugars. Based on these findings, it is crucial to tailor a specific nutrient management plan to compensate any imbalances in the field.

Effect on sugarcane yield as influenced by different planting methods and intercrops.

Number of millable canes (`000 ha^{-1})

The study highlights the significant impact of various planting methods and intercropping systems on the number of millable sugarcane canes. It observed that sugarcane planted with traditional spacing (90 cm in furrows) yielded a higher number of millable canes (116.67) in comparison to the sole plant row spacing (PRS) system (60 x 60 – 120 cm), where the number of millable canes was 104.04. However, the final cane yield was superior in the sole PRS system, with a yield of 84.69 t ha^{-1}, as opposed to the traditional spacing system's yield of 77.82 t ha^{-1}.

© 2025 AATCC Review. All Rights Reserved.

This discrepancy can be attributed to the greater individual cane weight (814 g) observed in the T2 treatment within the PRS system. In terms of intercropping systems, the count of millable canes was noticeably higher in the paired row planted sugarcane when intercropped with vegetable pea (T5), recording a total of 97800 millable canes. This count was comparable to paired row planted sugarcane intercropped with potato (T3) with 92970 canes and sole sugarcane planting (T1) with 116670 canes, over the rest of the treatments. The lowest count of millable canes was seen in paired row planted sugarcane intercropped with lentil (T6), recording 84410 millable canes. These observations align with the findings of Raskar and Bhoi [30], reinforcing the influence of planting methods and intercropping systems on the number of millable canes.

Cane yield (t ha^{-1})

The data revealed that the treatment involving the sole paired row planting of sugarcane intercropped with gram (T7) significantly outperformed treatments T1 to T5 in terms of cane yield, producing an impressive 96.73 t ha^{-1}. This yield, however, was found to be statistically similar to that observed in treatments T6 and T7, in ascending order.Among all the planting methods evaluated, the sole paired row planting method produced a notably higher cane yield (84.69 t ha^{-1}) compared to the conventional planting method (77.82 t ha^{-1}). This trend aligns with previous findings reported by Zarekar [39], highlighting the potential advantages of employing paired row planting over traditional methods. Furthermore, the yield results underscored the benefits of incorporating potato and legume crops in sugarcane intercropping systems. The observed yield boost can likely be attributed to reduced interspecies competition [7]. Intercropping systems involving these crops might be promoting better resource utilization, thus enhancing the overall productivity of the system. These findings emphasize the need to consider alternative planting techniques and intercropping systems, like sole paired row planting and intercropping with gram, to maximize sugarcane yield.

Green top yield (t ha^{-1})

The collected data highlighted a clear difference in green top yield based on both planting methods and intercropping systems. It was observed that conventional sugarcane planting (90 cm in furrows) yielded a lower green top output (9.19 t ha^{-1}) in comparison to the sole paired row planting of sugarcane (60 x 60 – 120 cm), which recorded a higher green top yield of 10.48 tha^{-1}. This suggests that the paired row planting method could potentially enhance the production of green tops. When evaluating the different intercropping systems, the paired row planting of sugarcane intercropped with pea (T7) was observed to produce the highest yield of green tops, amounting to 14.69 tha^{-1}. This yield was significantly higher compared to all other treatments, implying that the incorporation of pea into the sugarcane plantation might have beneficial effects on green top production. Conversely, the lowest yield of green tops was associated with treatment T3 (PRS + potato), recording a yield of only 10.76 tha^{-1}. The results emphasize the influence of the choice of intercrop on the green top yield and suggest the need for careful selection and management of intercropping systems to optimize the yield of green tops.

Trash yield (t ha^{-1})

The data, as outlined in Table 4, pointed out significant variations in trash yield, depending on the sugarcane planting method and intercropping system. The highest trash yield of 9.98 tha^{-1} was recorded when sugarcane was paired row planted and intercropped with gram, outperforming sugarcane planted at conventional spacing (90 cm in furrows) and sole paired row sugarcane (60 x 60 – 120 cm). However, this yield was found to be statistically similar to the yields from the rest of the treatments. Sole paired row sugarcane demonstrated a slightly higher but statistically equal trash yield compared to conventionally planted sugarcane (90 cm in furrows). The superior yield from the wider spacing is likely attributable to enhanced photosynthetic accumulation due to increased availability of resources such as sunlight, water, and nutrients. This finding aligns with the results reported under reference [31], [8] is reinforcing the advantages of wider row spacing and intercropping with gram to maximize trash yield.

Intercrop yield (t ha^{-1})

The results provided insights into the yield variations across different intercropping systems paired with sugarcane. The highest yield was achieved from the intercrop of potato, which recorded a significant output of 20 tha^{-1}. Next to potato the green pod of pea, this generated a substantial yield of 5.0 tha^{-1}. Intercrops such as coriander, lentil and gram yielded lower but still meaningful outputs of 2.5 tha^{-1} and 2.0 tha^{-1}, respectively. Rajmah, recorded the lowest intercrop yield at 1.2 tha^{-1}.From these findings, it can be inferred that vegetable intercrops may offer more economically viable options, contributing to greater additional benefits compared to seed type intercrops. This observation may influence strategic decisions regarding the selection of intercrops for maximizing economic returns. However, it's also noteworthy that intercrops like gram, pea, and Rajmah serve a complementary role, enhancing the soil fertility status and consequently benefiting the yield of the main crop, sugarcane. These results are consistent with the findings of Meena *et al.,* [25], is reinforcing the value of diversified intercropping systems. More recent studies have also suggested that well-designed intercropping systems can increase agricultural sustainability by promoting resource use efficiency, improving soil health, and enhancing crop resilience to environmental stresses. These findings underline the need to optimize the selection and management of intercrops in sugarcane cultivation to improve yield outputs and enhance economic returns while improving soil fertility.

Effect on nutrient content and uptake by sugarcane

Table 5 provides a comprehensive breakdown of the impact of various planting methods and intercrops on the total nutrient content and uptake of nitrogen, phosphorous, and potassium by the sugarcane. The influence of these factors on nutrient content and uptake is critical in understanding the optimal conditions for sugarcane growth and productivity. Nutrient uptake is a crucial process for the growth and development of plants, allowing them to obtain the necessary elements required for various physiological functions. Nitrogen, phosphorous, and potassium are vital for contributing significantly to the plant's health and yield. The different planting methods and the introduction of intercrops might have influenced the nutrient availability and absorption efficiency of the sugarcane. Each treatment likely created unique soil conditions and microenvironments affecting the nutrient dynamics in the soil-crop system.

Nutrient content (%) in sugarcane

The content of nitrogen, phosphorous, and potassium in sugarcane harvested under various planting methods and intercropping systems was notably influenced by different treatments. Nitrogen (N), phosphorus (P) and potassium (K) are macronutrients vital for growth and yield. Hence, the quantity of

© *2025 AATCC Review.* All Rights Reserved.

these nutrients in sugarcane plants can significantly influence plant health and productivity. Specifically, the highest nitrogen content (1.83%) was recorded in the sugarcane plants when they were paired row-planted and intercropped with Rajmah (T4). This indicates that the intercropping of Rajmah may foster a more favourable environment for nitrogen availability and uptake. Nitrogen is a vital component of proteins, enzymes and chlorophyll; hence its enhanced content can contribute better growth and yield. In contrast, the highest phosphorus content (0.29%) was noted when sugarcane was paired row planted and intercropped with lentil (T6). Phosphorus is crucial for energy transfer and storage in plant cells, so its high content may boost metabolic efficiency and productivity. Furthermore, sugarcane plants intercropped with coriander under the paired row planting method (T8) recorded the highest potassium content (2.35%). Potassium is essential for various physiological processes in plants, including photosynthesis, protein synthesis, and water uptake, so a higher content may enhance yield. These findings align with recent studies highlighting the influence of intercropping systems on nutrient content and uptake in various crops [22], [16]. It's suggested that intercropping can enhance nutrient use efficiency, improve soil fertility and potentially increase crop yield and quality.

Nutrient uptake by sugarcane (kg ha^{-1})

The total uptake of N, P, and K by sugarcane, as depicted in Table 5, displayed significant differences in response to various planting methods and intercropping systems. Nitrogen, phosphorus, and potassium are crucial nutrients that influence the growth and yield of crops and their efficient uptake is vital for optimizing productivity. When comparing paired row planting with conventional planting, the paired row planting method recorded a higher uptake of N, P and K, specifically, 189.12 kg ha^{-1}, 13.98 kg ha$^{-1,}$ and 274.89 kg ha^{-1}, respectively. This suggests that the paired row planting, by modifying root exposure and soil contact, may enhance nutrient accessibility and uptake. Examining the influence of different intercropping systems on nutrient uptake, the treatment involving paired row sugarcane planting intercropped with pea (T5) yielded the highest uptake of N, P, and K, recording values of 230.21 kg ha^{-1}, 15.13 kg ha^{-1} and 291.42 kg ha^{-1}, respectively. This could be attributed to the leguminous nature of peas, which can fix atmospheric nitrogen that's readily available for plant uptake, thereby increasing nitrogen availability and enhancing overall crop yield. Conversely, treatment T6 (PRS + coriander) recorded the lowest uptake of N, P and K compared to all other treatments, with values of 201.11 kg ha^{-1}, 13.18 kg ha^{-1} and 275.98 kg ha^{-1}, respectively. These findings corroborate with recent studies highlighting the influence of different planting methods and intercropping systems on nutrient uptake by crops. [46] reported that intercropping leguminous crops can enhance N uptake due to the legume's ability to fix atmospheric nitrogen.

Total uptake of phosphorus (kg ha^{-1})

The total uptake of phosphorus by the sugarcane was significantly affected by the chosen planting spacing and intercropping systems, demonstrating the crucial role of these factors in influencing nutrient absorption. Phosphorus is a key nutrient for plants, playing vital roles in energy transfer, nutrient transport, photosynthesis and other physiological processes. The highest phosphorus uptake was observed in the paired row planting of sugarcane intercropped with pea (T5), recording a phosphorus uptake of 15.13 kg ha^{-1}. This finding is likely due to the ability of pea plants, as legumes, to facilitate better phosphorus availability and uptake, possibly through root interactions and soil microbe stimulation [11]. Conversely, the lowest phosphorus uptake was noted in the sole sugarcane treatment with conventional planting (90 cm), which recorded an uptake of 12.95 kg ha^{-1}. This suggests that the conventional planting method may not be as efficient in promoting phosphorus uptake as the paired row planting method, especially when combined with suitable intercrops such as peas. These findings align with recent studies of Li *et al.,* [21] found that intercropping systems could enhance phosphorus use efficiency and uptake in various crops. This implies that careful selection and management of planting methods and intercropping can contribute to P uptake, potentially leading to healthier crops and higher yields.

Total uptake of potassium (kg ha^{-1})

The s results, as presented in Table 5, showed a noticeable impact of planting methods and intercropping systems on K uptake by the sugarcane crop. Potassium plays a crucial role in a wide range of plant physiological processes, including protein synthesis, photosynthesis and disease resistance, making its efficient uptake vital for crop health and productivity. Sole paired row planting (60 x 60 - 120 cm) recorded numerically superior values of K uptake (274.89 kg ha^{-1}) compared to conventional sugarcane planting (90 cm). This suggests that the paired row planting method may foster an environment more conducive to K absorption. Concerning different intercropping systems, sugarcane paired row planted and intercropped with pea (T5) demonstrated the highest potassium uptake, specifically 291.42 kg ha^{-1}, compared to other treatments. In contrast, paired row planting of sugarcane intercropped with lentil (T6) displayed a lower uptake of K, recording 275.98 kg ha^{-1}. The enhanced uptake in the pea intercrop could be due to synergistic root and microbial interactions enhancing nutrient availability and uptake. The efficiency of fertilizer use was marginally higher when sugarcane was intercropped with pea, gram and rajmah. This finding aligns with a study by Kumar *et al.*, [20], which reported similar observations with different intercrops. On the other hand, the least nutrient uptake was recorded when sugarcane was intercropped with lentils and potato. Potatoes, known for their high nutrient demand, may compete with sugarcane for nutrients, leading to reduced uptake and potential adverse effects on sugarcane growth. Wide spacing of sugarcane (60 x 60 - 120 cm) registered significantly higher uptake compared to normal spacing (90 cm). Similar results were reported by Patel *et al.*, [28], suggesting that careful management of planting spacing can improve nutrient absorption, subsequently leading to better crop health and productivity.

Effect on Availability of nutrient in soil after harvest of sugarcane crop

Table 6 presents the impact of various treatments on the available N, P and K of soil after the harvest of sugarcane. Sugarcane utilizes a significant amount of nutrients from the soil during its growth. Therefore, after the harvest, nutrient in the soil such as nitrogen, phosphorus and potassium, are usually depleted to some extent. Over time, continuous cultivation and harvesting of sugarcane without proper soil management practices can lead to nutrient exhaustion, reducing soil fertility and affecting future crop yields. Therefore, it's crucial to replenish these nutrients through fertilization and other soil management practices.

© *2025 AATCC Review.* All Rights Reserved.

These can include crop rotation, use of green manure or cover crops and application of organic or synthetic fertilizers.

Available nitrogen in soil (kg ha^{-1})

The data displayed in Table 6 explores the mean values of available N, P and Kin soil under sugarcane cultivation after harvest. The results indicate a substantial amount of nutrients remain in the field post-harvest, which can be utilized by the succeeding crop. The amount of available N, P and K in the soil varied significantly based on the treatments applied, namely the planting methods, spacing, and intercropping systems. Among the treatments, the paired row planted sugarcane intercropped with lentil (T6) exhibited the highest values of available nitrogen (298.16 kg ha^{-1}). Conversely, the treatment T8 (PRS + coriander) showed the lowest nitrogen availability at 291.19 kg ha^{-1}. For phosphorus, the highest value (14.11 kg ha^{-1}) was observed with PRS intercropped with Pea (T5). As for potassium, the PRS intercropped with coriander (T8) recorded the highest value (282.18 kg ha^{-1}) in the soil after harvest. The variations in nutrient availability were significant with nitrogen remaining unaffected by different planting methods and intercrops. Legume intercrops in cropping systems, such as lentils and peas, enhance soil fertility through the excretion of amino acids, carbohydrates, sugars, tannin, lignins, etc., into the rhizosphere. This excretion promotes the population of beneficial microfauna. The nitrogen fixed by the legume intercrop might be available to the associated sugarcane in the current season itself, as sugarcane stays in the field for more than nine months after the harvest of the legumes. Another possibility for improving soil fertility is through the addition of intercrop residues. These residues, upon decomposition, can enhance the fertility of the soil. Considering the nutrient addition through intercropping, there may be a possibility of reducing N application via chemical fertilizer [10], [46], [47]. Traditionally, the optimal row spacing recommended for sugarcane is 90 cm, a practice widely followed in tropical India. However, with the introduction of high tillering and high yielding varieties of sugarcane, there is potential to adopt wider row spacing without affecting cane productivity. Such an approach would permit intercropping thus increasing the overall productivity and profitability of the system [36].

Available phosphorus in soil (kg ha^{-1})

The data about the available phosphorus in the soil post sugarcane harvest showed that the various treatments, including planting methods, spacing and intercropping, significantly influenced the availability of this nutrient in the soil. Specifically, the T5 treatment - paired row planting sugarcane intercropped with pea recorded the highest availability of phosphorus at 14.11 kg ha^{-1}, compared to the rest of the treatments. Conversely, the lowest availability of phosphorus (12.99 kg ha^{-1}) was observed in the T4 treatment, which involved paired row planting of sugarcane intercropped with rajmah. The variations observed in phosphorus availability across different treatments illustrate the significant influence of planting methods, spacing and intercropping choices on the nutrient content of the soil following sugarcane harvest. In this case, the intercropping of sugarcane with pea (T5 treatment) demonstrated a higher concentration of available phosphorus compared to the sugarcane intercropping with rajmah (T4 treatment). This result aligns with previous research demonstrating that the choice of intercrop can have a substantial impact on nutrient cycling and availability within agricultural systems. Specifically, leguminous intercrops like peas are known to increase the availability of nutrients due to their ability to fix atmospheric nitrogen and enhance soil fertility [6], [45]. Conversely, the lower phosphorus levels observed in the rajmah intercropped plots could be due to this crop's higher phosphorus uptake, leaving less available in the soil post harvest. These findings emphasize the importance of carefully selecting intercrop species to optimize soil nutrient availability. Such knowledge is key to developing improved agricultural practices that maintain soil health and productivity while minimizing the need for external inputs.

Available potassium in soil (kg ha^{-1})

The analysis of available potassium in the soil post-harvest of sugarcane reveals significant differences due to various planting methods and intercrop choices. Specifically, the maximum availability of potassium was observed under treatment T8 (Paired Row Sugarcane + Coriander), which recorded a concentration of 282.18 kg ha^{-1}, higher than the rest of the treatments. The lowest potassium availability was observed with sugarcane-paired row planting intercropped with lentils, at a concentration of 262.15 kg ha^{-1}. The observed variability in potassium availability, which was influenced significantly by different planting methods and intercrop choices, underlines the impact of these agronomic practices on soil nutrient status following a sugarcane harvest. Notably, the T8 treatment (Paired Row Sugarcane + Coriander) led to the highest available potassium in the soil. This could be related to the properties of coriander as a crop, which is not known to have high potassium requirements, thus leaving a higher amount available in the soil after harvest [3], [41], [42]. In contrast, the lowest potassium availability was associated with sugarcane intercropped with lentils. This may be due to the relatively higher potassium uptake by lentils compared to coriander, thereby reducing the residual potassium in the soil. These findings emphasize the importance of crop selection in intercropping systems, as different crops can significantly affect the postharvest availability of nutrients in the soil [43], [44]. Knowledge of these interactions can guide the development of sustainable practices, optimizing nutrient utilization while minimizing reliance on external inputs.

Conclusion

Intercropping with gram and coriander produced the highest yields when planted in paired rows with sugarcane. This indicates that these crops are highly compatible with sugarcane and enhance overall productivity in an intercropping system. Specifically, gram emerged as an ideal choice for intercropping with paired row planted sugarcane, due to its lower nutrient requirements and beneficial impacts on soil health. Additionally, the study found that fertilizer use efficiency was slightly higher when sugarcane was intercropped with pea and rajmah. This suggests that these intercrops can improve nutrient uptake and utilization in sugarcane, thereby enhancing the efficiency of fertilizer application. Overall, these findings offer valuable insights for optimizing sugarcane cultivation practices in the Northwest alluvial plains of Bihar. They underscore the potential benefits of intercropping and paired row planting in maximizing crop yield and improving nutrient utilization. Consequently, these practices significantly contribute to sustainable sugarcane cultivation, promoting both agricultural productivity and environmental sustainability.

© 2025 AATCC Review. All Rights Reserved.

Future Scope of the Study

The findings from this study underscore the potential of paired row planting and strategic intercropping to enhance sugarcane yield and nutrient absorption, offering significant economic and environmental benefits. Future research could explore the long-term impact of these practices on soil health and nutrient dynamics, focusing on diverse agroecological zones. Investigating the feasibility of integrating additional high-value intercrops and assessing their economic viability could provide farmers with broader income opportunities. Moreover, leveraging precision agriculture technologies to optimize planting patterns and nutrient management strategies may enhance resource use efficiency. Such advancements could further refine sustainable cultivation practices, ensuring agricultural productivity while addressing the challenges posed by climate change and limited land resources.

Acknowledgement

The authors express their gratitude to the Director, Sugarcane Research Institute, Rajendra Prasad Central Agricultural University, Pusa, for approving the station trial "Effect of planting method and intercropping on yield, nutrient content, and uptake by autumn sugarcane at RRS Madhopur." We are also deeply appreciative of the technical staff of the RRS, whose invaluable assistance greatly contributed to the success of this study. Their unwavering support and commitment were integral to the completion of this research.

Conflict of interest: The authors declare that they have no conflict of interest.

Table 1: Preliminary Report of Soil Analysis for the Experimental Site

Soil parameters	Value	Category (L/M/H)
P^H (1:2.5)	8.28	Saline
EC (dS/m) (1:2.5)	0.73	Normal
Organic carbon (%)	0.61	Medium (0.5-0.75)
Available Nitrogen (kg ha^{-1})	265	Medium (250-560)
Available P_2O_5 (kg ha^{-1})	22	Medium (10-25)
Available K_2O(kg ha^{-1})	172	Medium (110-280)
Available zinc (ppm)	0.65	Medium (0.50 - 1.00)
Available boron (ppm)	0.31	Low (< 1.0)

Table 2: Climatic Data from RRS Madhopur

Months	Rainfall (mm)	Temperature (^{0}C) Maximum	Minimum	Humidity (%)
April	12.54	35.50	22.41	75.52
May	91.03	36.33	21.89	42.33
June	145.0	39.17	27.10	54.70
July	329.0	27.84	19.10	86.72
August	109.0	29.12	26.40	84.18
September	401.0	29.95	23.73	45.68
October	52.0	29.50	24.46	65.56
November	12.9	25.80	18.80	83.88
December	28.4	19.37	12.95	87.29
January	2.50	18.32	12.81	86.23
February	11.3	27.5	17.57	84.36
March	148.0	32.5	21.97	80.94

Table 3: Recommended Guidelines for Fertilizer Dosage, Seed Rate, Varieties Spacing and Yield in Intercropping

Intercrops	RDF N: P_2O_5: K_2O	Seed rate ha^{-1}	varieties	Spacing	Lines	Yield (Q/ha)
Sugarcane	150: 85:60	30,000 setts	CoP-16437	As per treatment		
Potato	150:90:100	20 q/ha	Kufriashok	20	6	200
Rajmah	100:50:30	60 kg/ha	PDR-14	30×10	4	12
Pea (pods)	20:45:20	40 kg/ha	Harbhajan	20×10	6	50
Lentil	20:45:20	15 kg/ha	PL-77	30	4	20
Gram	20:45:20	40 kg/ha	Pusa-372	30×10	4	25
Coriander	60:40:30	12 kg/ha	R. Dhaniya-1	30×20	4	20

Table 4: Influence of diverse planting methods and intercropping systems on sugarcane and intercrop yield attributes.

Treat. No.	No. of millable canes (`000 ha^{-1})	*SCW (g)	Cane yield (t ha^{-1})	Green top yield (t ha^{-1})	Trash yield (t ha^{-1})	Intercrops yield (t ha^{-1})
T_1	116.67	667	77.82	9.19	7.08	-
T_2	104.04	814	84.69	10.48	8.33	-
T_3	92.97	923	86.65	10.76	8.82	20.0
T_4	88.29	945	79.76	11.03	8.13	1.2
T_5	97.80	918	89.78	12.67	8.92	5.0
T_6	84.41	1022	90.23	13.69	9.51	2.0
T_7	89.65	1079	96.73	14.69	9.98	2.0
T_8	88.33	1058	93.45	13.96	9.92	2.5
SE ±	3.87	33.94	2.09	0.37	0.04	0.23
C.D. at 5%	11.24	90.96	6.82	1.15	0.19	0.69
Mean value	95.27	928.25	87.39	12.06	8.84	5.45

**SCW: single cane weight*

© *2025 AATCC Review.* All Rights Reserved.

Table 5: Impact of various planting and intercropping systems on plant nutrient content (%) and uptake (kg ha^{-1}).

	Treatments	Nutrient content (%)			Nutrient uptake (kg ha^{-1})		
		N	P	K	N	P	K
T_1	Sole sugarcane -90 cm	1.45	0.11	2.19	182.21	12.95	258.62
T_2	Sole paired row sugarcane (60 × 60 cm-120cm)	1.48	0.12	2.22	189.12	13.98	274.89
T_3	Paired row sugarcane (PRS) + Potato	1.49	0.19	2.25	213.18	14.81	286.88
T_4	Paired row sugarcane (PRS) + Rajmah	1.83	0.21	2.29	218.14	14.93	284.45
T_5	Paired row sugarcane (PRS) + Pea	1.51	0.22	2.31	230.21	15.13	291.42
T_6	Paired row sugarcane (PRS) + Lentil	1.52	0.29	2.24	201.11	13.18	275.98
T_7	Paired row sugarcane (PRS) + Gram	1.50	0.20	2.28	211.21	14.99	278.49
T_8	Paired row sugarcane (PRS) + Coriander	1.53	0.18	2.35	221.15	15.12	281.27
	SE ±	0.05	0.03	0.07	0.03	0.17	9.35
	C.D. at 5%	0.12	0.11	0.21	22.26	0.62	28.12
	Mean	1.54	0.19	2.27	208.29	14.39	279

Table 6: Average available nitrogen (N), available phosphorus (P), and available potassium (K) in soil after sugarcane harvest, influenced by different planting methods and intercropping systems.

	Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Sole sugarcane-90 cm	286.08	12.21	251.23
T_2	Sole paired row sugarcane (60 × 60 cm-120cm)	290.18	12.98	256.12
T_3	Paired row sugarcane (PRS) + Potato	293.82	13.85	264.98
T_4	Paired row sugarcane (PRS) + Rajmah	292.63	12.99	275.96
T_5	Paired row sugarcane (PRS) + Pea	295.72	14.11	280.10
T_6	Paired row sugarcane (PRS) + Lentil	298.16	13.94	262.15
T_7	Paired row sugarcane (PRS) + Gram	293.23	13.96	273.19
T_8	Paired row sugarcane (PRS) + Coriander	291.19	13.78	282.18
	SE ±	5.67	0.36	9.84
	C.D. at 5%	19.20	1.06	29.53
	Mean	292.62	13.48	268.23

Reference

1. Alam MJ, Rahman MM, Zaman AKMM. (2000) Impact of paired row Sugarcane with double intercrops. *Bangladesh Journal of Sugarcane*; 22 (2):1-9.

2. Berger KC, Truog E (1939) Boron determination in soils and plants. *Industrial and Engineering Chemistry*, Analytical Edition 11: 540-545.

3. Dong H, Li W, Tang W, Zhang D (2018) Role of Potassium in Plant Cultivation and Progress in Potassium Fertilizer. *Journal of Plant Nutrition and Fertilizer*: 24 (6): 1863-1874.

4. Kumar, Ajeet (2015) Spatial Distribution of Macro and Micro Nutrients in soils of Saharsa district of Bihar. *An Asian Journal of Soil Science* (An International Refereed Research Journal). 10 (2): 276-282. https://hal.science/hal-04676717.

5. Estrada-Bonilla GA, Durrer A, Cardoso EJBN (2021) Use of compost and phosphate solubilizing bacteria affect sugarcane mineral nutrition, phosphorus availability and the soil bacterial community. *Applied Soil Ecology*. 157: 103760.

6. Ghosh PK, Mohanty M, Bandyopadhyay KK, Painuli DK, Misra AK (2019) Growth competition, yields advantage and economics in soybean/pigeon pea intercropping system in semi-arid tropics of India. Effect of nutrient management.*Field Crops Research*, 118: 25-32.

7. Kumar, Ajeet and Choudhary, A. (2016) Constraints to cabbage (*Brassica oleracea* var. *capitata* L.) production in peri-urban area of Saharsa district in Bihar. *An Asian Journal of Soil Science* (An International Refereed Research Journal). 11 (2): 297-306. https://hal.science/hal-04676725

8. Kumar, Ajeet., Singh, S.K. ., Meena, S.K., Sinha, S., Rana, L., Kumari, A., Singh, A.K ., & Kumar, A. . (2024). Human Health Risk Assessment of Nitrate-Contaminated Groundwater in North East Alluvial Plains of India. **In Book**: Geography, Earth Science and Environment: Vol. 2, 3 December 2024, Page No.: 1-26**.** Print ISBN: 978-93-48388-08-7, eBook ISBN: 978-93-48388-35-3. *Geography, Earth Science and Environment: Research Highlights Vol. 2*, 1–26. https://doi.org/10.9734/bpi/geserh/v2/1424

9. Jackson, ML 1973. Soil chemical analysis, pentice hall of India Pvt. Ltd., New Delhi, India, 498, 151-154.

10. Kailasam C (1994) Effects of Intercropping and Nitrogen Application in Sugarcane Cultivation.*Journal of Agronomy and Crop Science*, 172 (5): 305-311.

11. Kumar A and PaswanD (2015) Response of pea (*Pisumsativum* L.) to *Rhizobium* inoculation and nitrogen application in soils of North East Alluvial plains of Bihar.*AnAsian Journal of Soil Science*. 10 (2): 252-258.DOI: *10.15740/HAS/AJSS/10.2/252-258*.

© *2025 AATCC Review.* All Rights Reserved.

12. Kumar A, Chattopadhyay S and Meena SK (2023a) Soil Fertility Assessment of Sugarcane Growing Villages in Samastipur District of Bihar.*Environment and Ecology.*41 (2): 759-764.https://doc.article-environmentandecology.com/external/file/15vy05a767e7a4e17435695f722fc209e2248

13. Kumar A, Choudhary A,Kumar M (2018)Impact of climate change and their mitigation for better sugarcane production-A Review; *International Journal of Agricultural Sciences.* 14 (2): 431-441. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20183280336

14. Kumar A, Meena SK, Singh SK, Sinha SK,Singh AK (2024b) Carbon sequestration in sugarcane plant - soil system as influenced by nutrient integration practices under Indo-Gangetic plains of India.*Journal of Advances in Biology & Biotechnology.27*(5), 116–125. https://doi.org/10.9734/jabb/2024/v27i5769.

15. Kumar A, MeenaSK, Sinha SK, Singh AK, Minnatullah, Singh SK (2024a) Isolation and biochemical characterization of endophytic bacterium *Gluconacetobacter diazotrophocus* from native sugarcane cultivar of middle gangetic plains of India. *Indian Journal of ecology*, 51(1): 104-112. https://doi.org/10.55362/IJE/2024/4202.

16. Kumar A, Paswan D, Choudhary CS, Kumar B, Arun A (2014) Ameliorating the effects of climate change through organic agriculture system-*A Review. An Asian Journal of Soil Science* (An International Refereed Research Journal).9 (2): 318-324.http://researchjournal.co.in/online/AJSS/AJSS%209(2)/9_318-324_A.pdf.

17. Kumar A,Singh SK, MeenaSK, SinhaSK, Rana L (2024c) Groundwater contamination with nitrate and human health risk assessment of North East alluvial plains of Bihar.*International Journal of Environment and Climate Change*, 14(3), 17–31. https://doi.org/10.9734/ijecc/2024/v14i34016; https://hal.science/hal-04484961

18. Kumar A, Sinha SK, Kumar N, Rana L,.Singh AK(2023b) Impact of intercrops and planting methods on yield and nutrient uptake by sugarcane under North West alluvial plains of Bihar. *Preprint*: https://doi.org/10.21203/rs.3.rs-3763534/v1.

19. Kumar, B., Sinha, SK., Kumar, A, and Kumari, A. (2024). Exploring the Impact of Organic-Inorganic Coupling on Nutrient Use Efficiency and Cane Yield in Calcareous Soils of the Indo-Gangetic Plains of India. *Journal of Advances in Biology & Biotechnology*, 27(6), 644-656. https://doi.org/10.9734/jabb/2024/v27i6924

20. Kumar N, Sow S, Rana L,SinghAK, KumarA,Kumar A, Singh SN (2023c) Physio-agronomic performance of sugarcane (*Saccharum* spp. hybrid complex) genotypes to various planting geometry.*Annals of Agricultural Research Series, 44 (1): 93-98.* https://epubs.icar.org.in/index.php/AAR/article/view/134796

21. Li L, Sun J, Zhang F, Li X, Yang S, Rengel Z (2019) Wheat/maize or wheat/soybean strip intercropping. I. Yield advantage and interspecific interactions on nutrients. *Field Crops Research*, 71(1): 123-137.

22. Li Y, Liu M, Wang S, Zhang T, Du Q, Wang Y, Cao G (2020) Intercropping improves soil nutrient availability, soil enzyme activities and tea yield and quality. *Scientific Reports*, 10(1): 1-11.

23. Lindsay WL, Norvell WA (1978) Development of a DTPA soil test for zinc, iron, manganese and copper.*Soil Science Society of America Journal* 42: 421-428.

24. Kumar, Ajeet and Mukul Kumar (2017) Effect of different levels of phosphorus on the yield and yield components of maize under agro-climatic zone- II of Bihar. *International Journal of Agricultural Sciences.* 13 (2): 266-270. https://hal.science/hal-04676729.

25. Meena SK, Kumar A, Singh AK (2023) Organic amendment management: Impact on carbon dynamics, sugarcane quality and productivity, Pg. 341-363. In Book: Agricultural soil sustainability and carbon management" Elsevier Publication (Academic Press), Cambridge. https://doi.org/10.1016/B978-0-323-95911-7.00013-X.

26. Meena SK, KumarA, Meena KR, Sinha SK, Rana L, Singh AK,ParewaHP,MeenaVS (2024). Advanced and Emerging Techniques in Soil Health Management. Pages: 343-362; In: Bhatia, R.K., Walia, A. (eds) Advancements in Microbial Biotechnology for Soil Health. Microorganisms for Sustainability, vol 50.Springer, Singapore. https://doi.org/10.1007/978-981-99-9482-3_15

27. Panse VG, Sukhatme PV (1967) Statistical methods for Agricultural workers. ICAR Publications, New Delhi, 1967: 199-210.

28. Ajeet Kumar, S.K. Meena, S.K. Singh, S.K. Sinha, Amrita Kumari and A.K. Singh (2024) Chapter-7- Title Understanding Carbon Sequestration in Sugarcane Plant-soil System: Influence of Nutrient Integration Practices in Indo-Gangetic Plains of India. In Book: *Research Advances in Environment, Geography and Earth Science*. Volume.9. 7 October 2024, Page No.: 84-102. https://doi.org/10.9734/bpi/raeges/v9; https://doi.org/10.9734/bpi/raeges/v9/1425.

29. Rana L, Kumar N, Rajput J, Kumar A, Nalia A, Singh AK (2023) Planting Methods Enhanced the Cane Yield and Input Use Efficiency in Sugarcane-An Overview., International Journal of Bio-resource and Stress Management, 14(10): 1448-1453. HTTPS://DOI.ORG/10.23910/1.2023.4791c

30. Raskar BS, Bhoi PG (2003) Yield attributes of sugarcane as influenced by intra-row spacing, fertilizer levels and planting materials. *Indian Sugar*. 53 (5): 327-331.

31. Singh GD, Saini SK, Bhatnagar A (2010) Effect of planting methods and irrigation scheduling on growth, yield and quality of spring planted sugarcane. *Agriculture Research New Series*; 33(1): 21-24.

© *2025 AATCC Review.* All Rights Reserved.

32. Singh SP, Nema S, Kumar A, Minnatullah, Kumar N (2024). Resource Use and Technical Efficiency of Soybean Production in Madhya Pradesh: A Data Envelopment Analysis Approach.Journal of Advances in Biology & Biotechnology, 27(5), 551 - 557. https://doi.org/10.9734/jabb/2024/v27i5817.

33. Singh SK, Tagung T, Kumar A, Singh KK, Tiwari S, Kashiwar SR, Kumar A, Kumari S, and Singh YB (2024a). Geospatial Analysis of Soil Fertility in Muzaffarpur District, Bihar, India: Integrating GPS and GIS Technologies. Journal of Advances in Biology & Biotechnology, 27(7), 1083-1093. https://doi.org/10.9734/jabb/2024/v27i71067.

34. Sinha SK, Kumar A, Kumari A, Singh AK(2024) The Integrated Effect of Organic Manure, Biofertilizer and Inorganic Fertilizer on Soil Properties, Yield and Quality in Sugarcane Plant-ratoon System under Calcareous Soil of Indo Gangetic Plains of India. *Journal of Scientific Research and Reports.*30(5):193-206. https://doi.org/10.9734/jsrr/2024/v30i51934

35. Subbiah BV, Asija GL (1956) A rapid procedure for the estimation of available Nitrogen in Soil.*CurrentScience.*25(8): 259-260.

36. Sundara B (1994) Intercropping in Sugarcane for Higher Productivity and Profitability. *Sugar Tech*, 6 (1-2): 17-24.

37. Walkley, A., and Black, C.A. (1934)An examination of the digestion method for determining soil organic matter and proposed modifications of the chromic acid titration method. *Soil Science* 37: 29-38.

38. Watanabe FS, Olsen SR (1965) Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. *Soil Sci. Soc. American Proceed.* 29: 677-678.

39. ZarekarVV, KapseVD, Ashwini RC, Gangawane SB (2018) Effect of intercropping and planting methods on yield, nutrient content and uptake by sugarcane under lateritic soil of Konkan region. *Journal of Pharmacognosy and Phytochemistry*. 7(1): 135-139.

40. Zhou Q, Chen J, Xing Y, Xie X, Wang L (2019) Influence of intercropping Chinese milk vetch on the soil microbial community in rhizosphere of rape. *Plant Soil*. 440: 85-96.

41. Ramjas Meena, Ajeet Kumar, Sunita Kumari Meena, Sanjay Kumar Singh and Mohit Bairwa (2024) Zinc-Solubilizing Bacteria: A Sustainable Approach for Enhancing Agricultural Productivity and Soil Health *NEW ERA AGRICULTURE MAGAZINE.* 3 (5): 90-95. https://hal.science/hal-04768233.

42. Ajeet Kumar, S.K. Sinha, Sunita Kumari Meena, Minnatullah and A.K. Singh (2024) Unlocking Nature's Fertilizers: Exploring Potassium Solubilizing Bacteria. *NEW ERA AGRICULTURE MAGAZINE.* 3 (1): 20-25. https://hal.science/hal-04788461.

43. Ajeet Kumar, S.K. Sinha, Sunita Kumari Meena, Minnatullah and A.K. Singh (2024) Bio-priming of Sugarcane Setts and Nodes: A Novel Technology for Enhancing Sugarcane Yield. *NEW ERA AGRICULTURE MAGAZINE.* 3 (4): 6-13. https://hal.science/hal-04722781.

44. Kumari S, Y.P Devi, I. Bhupenchandra, K.B Lakshmi, S. Kumari, A. Kumari and Kumar Ajeet (2021) Dietary Diversity with Dried Moringa Leave Powder and Amla Juice to Increase Haemoglobin level of Adolescent girls of Farm Families. Journal of Community Mobilization and Sustainable Development. 16(2): 619-625. https://hal.science/hal-04676951.

45. Kumar, Ajeet., Rai, A.K. and De, N. (2015) Influence of FYM and irrigation frequency on yield, vitamin and mineral contents of organic Cabbage (*Bracica oleracea*.var capitata). *An Asian Journal of Soil Science* (An International Refereed Research Journal). **10 (2): 215-221**. https://hal.science/hal-04676713.

46. S.P. Singh, Minnatullah and Ajeet Kumar (2021) Enhancing Farmer's Income through Sugarcane Based Pulse Inter Cropping System Under North Bihar Condition: Economic Perspective. Agriculture & Food: E-Newsletter; 3 (6): 176-178. https://www.researchgate.net/profile/Ajeet-Kumar-53/publication/364657469_Enhancing_Farmer's_Income_through_Sugarcane_Based_Pulse_Inter_Cropping_System_Under_North_Bihar_Condition_Economic_Perspective/links/63a2b8fbca6a9d254f8f5393/Enhancing-Farmers-Income-through-Sugarcane-Based-Pulse-Inter-Cropping-System-Under-North-Bihar-Condition-Economic-Perspective.pdf.

47. Singh, Sanjay Kumar, Techi Tagung, Ajeet Kumar, Pankaj Singh, Harendra Singh, Sumedh R. Kashiwar, Sanjay Tiwari, A.K. Singh, Shweta Kumari, and Y. V. Singh. 2024. Geo Spatial Assessment and Micronutrient Mapping of Calcareous Soils in Muzaffarpur District, Bihar, India. *Journal of Scientific Research and Reports*; 30 (11):155-65. https://doi.org/10.9734/jsrr/2024/v30i112543

© *2025 AATCC Review.* All Rights Reserved.