CONSERVATION AGRICULTURE STRATEGIES FOR IMPROVING CARROT GROWTH YIELD AND QUALITY IN ARECANUT CROPPING SYSTEM

ABSTRACT

Aim: The study aims to comprehensively assess the influence of conservation agriculture techniques, encompassing reduced tillage, cover cropping (live mulch) and nutrient levels on a range of growth parameters and the ultimate yield of crop.

Study Design: Randomized block experimental design.

Place and Duration of Study: Field experiments were conducted across two growing seasons *i.e.,* 2019-20 and 2020-21 during *Rabi* at Balindi research farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur.

Methodology: Study was conducted with seven treatments, each replicated thrice. Precise measurements and meticulous analyses were conducted on key parameters; unequivocally indicate that conservation agriculture practices exert a substantial influence on both the growth and yield.

Results: Among various nutrient levels, higher dose of fertilizer (T_4 - 120:90:120 NPK kg ha^{-1}) with berseem as a cover crop in the interspaces showed maximum vegetative growth *i.e.,* plant height and number of leaves plant^{-1} at all growth stages (30, 60 and 90 DAS) while decreasing trend was observed in yield parameters with higher levels of nutrient doses, medium level of fertilizer dose (T_5 - 90:60:90 kg ha^{-1} + berseem) recorded highest root length, diameter, weight and projected yield of 18.5cm, 3.58 cm, 118.37 g plant^{-1} and 26.63 t ha^{-1} respectively.

Conclusion: These findings underscore the considerable potential of conservation agriculture practices as a sustainable approach to optimize carrot crop production. This research contributes valuable scientific insights that hold significant implications for agricultural stakeholders, including farmers and practitioners, seeking to fine-tune carrot cultivation methodologies while concurrently fostering soil health and environmental sustainability.

Keywords: *Carrot, Conservation Agriculture, Tillage, Mulch, Fertilizer*.

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INTRODUCTION

Carrots (*Daucus carota* L.) are a pivotal component of global agriculture, acclaimed for their nutritional value and culinary versatility. It is a cold-weather vegetable belonging to ~~the~~ Apiaceae ~~family~~. They are cultivated extensively worldwide for their edible roots. Carrots are particularly renowned for their beneficial impact on eye health, owing to their high carotenoid content. Carotenoids are a class of phytochemicals that serve as precursors to vitamin A, making carrots a valuable resource in mitigatingthe risk of vitamin A deficiency [1]. Furthermore, carrots offer substantial nutritional value, containing significant quantities of essential nutrients such as protein, carbohydrates, dietary fiber, thiamine,

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riboflavin, iron, calcium, phosphorus, and vitamin C.The cultivation of carrots, like many crops, has traditionally ~~employed~~ relied onconventional agricultural practicesincluding intensive tillage~~that~~ which may compromise soil health and environmental sustainability. However, in recent years, the adoption of conservation agriculture (CA) methods has emerged as a promising approach to address these challenges.

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Conservation Agriculture is an innovative farming approach centered on preserving soil health through minimal soil disturbance, continuous soil cover, and crop diversity. By avoiding extensive tillage, maintaining a protective cover of crop residues or cover crops, and cultivating various plant species, it fosters biodiversity and encourages natural biological processes in the soil. These practices not only enhance the efficient use of water and nutrients but also bolster crop production over the long term. The overarching objective is to boost yields by nurturing soil fertility and mitigating yield risks associated with unpredictable rainfall patterns, as emphasized by [2] in 2014. In essence, Conservation Agriculture embodies sustainable and resilient farming practices that harmonize agricultural productivity with environmental stewardship.

Within perennial horticulture cropping systems, conservation agriculture presents an optimal approach for effectively managing soil health while simultaneously creating opportunities for crop diversification.According to the Ashok Dalwai Report on doubling farmers' income (2017), crop diversification and intensification are recognized as one of the most critical components for accomplishing the objective of doubling farmers' income by the year 2024 [3]. The integration of carrot cultivation into arecanutbased cropping systems presents a unique agricultural landscape. While CA has demonstrated significant benefits in various cropping systems*i.e.,*cereal crop based systems and its application within the context of arecanut and carrot cultivation remains an underexplored research domain. The synergy between these two crops presents a unique opportunity to unravel the potential of CA methods in fostering carrot crop resilience and overall agricultural sustainability.

The findings hold promise not only for enhancing carrot production but also for promoting sustainable and resilient arecanut-based agroecosystems, which are crucial for the livelihoods of many farmers in tropical regions. This research endeavors to contribute to the evolving discourse on sustainable agriculture, bridging the gap between the preservation of soil health, environmental conservation, and crop productivity.

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MATERIAL AND METHODS

Field experiment was conducted for two consecutive years *i.e.,* 2019-20 and 2020-21 at Balindi Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia,WestBengal,~~. The research station was~~ located at 22°57' N 88°32' E, with an altitude of 9.75 m asl~~above the mean sea level~~. Topographic

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situation of the experimental site comes under the well-drainedgangetic new alluvial soil (order: Inceptisol) of West Bengal having clay type of soil. Top soil texture was granular with an organic carbon content of 0.91%, pH level of 7.57, 227.8 kg of available nitrogen, 35.4 kg of available P_2O_5 (phosphorus), and an impressive 340.26 kg of available K_2O (potassium) per hectare (kg ha^{-1}).

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The agricultural approach in this study aligns with the sustainable land management practices. Specifically, in the interrow spaces of an arecanut plantation, minimal tillage techniques were employed during land preparation, diverging from the conventional and intensive practices commonly practiced by farmers. This choice was made to reduce soil disturbance and enhance soil health and structure, consistent with the principles of conservation agriculture.Plots of 6m x 2m were laid out in Randomized Block design with seven treatments replicated thrice. The treatment details are T_1: 120:90:120 NPK kg ha^{-1},T_2: 90:60:90 NPK kg ha^{-1}, T_3: 60:45:60 NPK kg ha^{-1} T_4: 120:90:120 NPK kg ha^{-1} + Berseem, T_5: 90:60: 90 NPK kg ha^{-1}+ Berseem, T_6: 60:45:60 NPK kg ha^{-1}+ Berseem, T_7: Control.

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Good quality seed of carrot cv. Nantes was sown during the first week of November in both the 2019-20 and 2020-21 growing seasons within the designated experimental plots.During the land preparation phase, shallow furrows with a depth of 1.5 cm were meticulously created at a uniform distance of 30 cm between the rows. The seeds were then sown in these furrows using a linesowing method, ensuring precise placement. Subsequently, the seeds were immediately covered with loose soil to facilitate germination and seedling emergence.Approximately 20 days after the initial sowing, a thinning operation was executed. This process aimed to maintain a consistent ~~plant~~ spacing of 10 cm between individual carrot plants, ensuring optimal growth conditions and reducing competition for resources.In accordance with the experimental design, different nutrient levels were applied to the plots to assess their impact on carrot growth. These treatments were carefully administered to understand their influence on crop development and yield.Furthermore, a complementary practice involved linesowing berseem seeds between the rows of growing carrot plants. This additional cultivation served to enhance soil health, adds nitrogen to the soil, suppress weeds and contribute to the overall sustainability of the agricultural system. This particular step was initiated after the emergence of carrot seedlings, as it was strategically timed to avoid competition between the two crops during their critical growth phases.The initial harvest of berseem occurred 40 days after sowing, followed by additional harvests at intervals of 20 to 25 days. The biomass obtained from these harvests was then incorporated into the experimental plots.

Comment [OP15]: Indicate the origin or precedence of the carrot seeds you used in the experiments

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RESULTS AND DISCUSSION

Plant height

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~~According to the principles of conservation agriculture, t~~The application of a higher dose of fertilizer has a notable impact on vegetative growth (Table 1). At 30 days after sowing (DAS), the

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application of fertilizer alone (T_1: 120:90:120 NPK kg ha^{-1}) led to an increase in plant height, reaching 32.6 centimeters. However, at 60 DAS and 90 DAS, when a higher nutrient dose was applied with mulch (T_4: 120:90:120 kg ha^{-1} + berseem), plant height exhibited even greater growth, measuring 51.8 centimeters and 60.68 centimeters, respectively. While lowest was in control (47.62 cm).

Comment [OAPB18]: Did you apply any statistical test to assess the differences between treatments?

Number of leaves

Similarly, at all growth stages (30, 60 and 90 DAS), T_4 (120:90:120 NPK kg ha^{-1} + berseem) exhibited a higher number of leaves, measuring 7.09, 9.46, and 13.05 respectively, while the control plots displayed the lowest leaf count (7.82).

Comment [OAPB19]: Did you applied any statistical test to assess the differences between treatments?

The experiment revealed a strong link between increased fertilizer use and vegetative growth *i.e.,* plant height and number of leaves, especially with higher nitrogen and potassium levels. Nitrogen is vital for processes like cell elongation, division, and protein synthesis, while potassium plays a key role in biochemical and physiological processes, including cell division, elongation, and carbohydrate metabolism [4]. These factors collectively promote vegetative growth and overall plant development~~, as supported by~~ [5]~~and consistent with findings from~~[6][7][8][9] [10] [11]

The synergy of fertilizer and mulch led to maximum plant height by providing ample nutrients and an ideal growth environment. Favorable soil moisture and temperature under mulch~~, as noted by [12],~~ further promoted plant development [12]. This highlights the importance of nutrient management and mulching for optimal plant growth and agricultural productivity.

Table 1: **Effect of conservation agriculture practices on plant height and number of leaves plant^{-1} of carrot**

Treatment	Plant height (cm)			Number of leaves		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
T_1	32.60	50.47	59.20	6.82	8.98	11.88
T_2	25.66	45.43	54.03	6.12	7.84	10.22
T_3	23.02	41.50	50.26	5.41	7.33	8.70
T_4	28.97	51.80	60.68	7.09	9.46	13.05
T_5	27.20	45.75	55.45	6.25	8.31	11.37
T_6	24.87	43.15	51.85	5.74	7.57	9.75
T_7	21.83	38.20	47.62	5.17	6.84	7.82
S.Em (±)	**0.52**	**0.31**	**0.28**	**0.13**	**0.22**	**0.42**
C.D(0.05)	**1.60**	**0.96**	**0.88**	**0.41**	**0.66**	**1.30**

Comment [OAPB20]: Transform this table into a line chart; it is more suitable for the interpretation of this type of data.

T_1: *120:90:120 NPK kg ha^{-1};* ***T_2:*** *90:60:90 NPK kg ha^{-1};* ***T_3:*** *60:45:60 NPK kg ha^{-1};*

T_4: *120:90:120 NPK kg ha^{-1} + Berseem;* ***T_5:*** *90:60: 90 NPK kg ha^{-1} + Berseem;*

T_6: *60:45:60 NPK kg ha^{-1} + Berseem;* ***T_7:*** *Control*

Root length (cm)

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In contrast to the dynamics observed in vegetative growth, it was discerned that the application of a medium dose of fertilizer in conjunction with mulch (90:60:90 NPK kg ha^{-1}+ berseem) yielded the most extensive root length, measuring 18.5 cm, closely ~~pursued~~ followedby a length of 17.90 cm observed in treatment T_2 (90:60:90 NPK kg ha^{-1}). Conversely, the control group (T_7) exhibited the most diminutive root length, measuring a mere 13.80 cm. The root length exhibited a marked increase concomitant with the ascending dosage of fertilizer, yet this pattern experienced a subsequent decline after reaching a certain threshold.

Comment [OAPB21]: You must discuss this results

Diameter of root (cm)

Similar to root length, T_5 (90:60:90 NPK kg ha^{-1} + berseem) showed the highest root diameter (3.58 cm), followed by 3.52 cm in T_2 (90:60: 90 NPK kg ha^{-1}). While lowest diameter of root (2.76 cm) was recorded under T_7 (Control).

Comment [OAPB22]: Did you applied any statistical test to assess the differences between treatments?

Root weight (g $plant^{-1}$)

Statistically significant variation due to different doses of NPK was found in root weight of carrot root. The maximum fresh root weight of 118.37 g was produced by the plant received 90:60: 90 NPK kg ha^{-1} + berseem followed by 111.30 g in T_2 (90:60: 90 NPK kg ha^{-1}) and 105.11 g in T_4 (120:90:120 NPK kg ha^{-1} + berseem). While the lowest weight (72.99 g) was obtained from T_7 (Control).

Comment [OAPB23]: Include the result of the test.

Projected root yield (t ha^{-1})

Among different treatments, overall projected yield, showed significant variation with highest root yield (26.63 t ha^{-1}) in T_5 (90:60:90 kg ha^{-1} + berseem) followed by 25.76 t ha^{-1} in T_2 (90:60: 90 kg ha^{-1}) and 24.55 t ha^{-1} in T_4 (120:90:120 NPK kg ha^{-1} + berseem). Lowest root yield (15.3 kg ha^{-1}) was found under T_7 (Control).

Comment [OAPB24]: Include the result of the statistical test.

Reduced tillage has been reported to enhance various soil physical properties, such as bulk density, porosity, penetration resistance, water content, aggregate stability, mean weight diameter, dispersion ratio, root penetration, water, and air permeability [16][17][18]. Additionally, it increases crop residue, keeping the soil surface cooler, reducing soil temperature, and minimizing water loss by evaporation. These combined effects enhance crop water use efficiency [19] [20].

In this study, reduced tillage significantly increased carrot yield compared to conventional tillage, aligning with prior research[13][14]. This enhancement in growth and yield is attributed to improved soil physical properties, including bulk density, porosity, and penetration resistance, which promote better root penetration and nutrient uptake, particularly N, P, and K, vital for carrot growth. Carrot performance is notably affected by N and K [15].

Comment [OAPB25]: In what crops?

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Comment [OAPB27]: Why do you assume that reduced tillage increased carrot yield when this could be attributed to N and K additions?

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Carrots are heavy feeders, especially for essential nutrients like N, P2O5, and K2O needed for growth and yield. Fertilizer and mulch, with minimum tillage, significantly influenced root yield (kg/plot) and projected root yield (t/ha). Increased yields from a fertilizer dose of 90:60:90 NPK kg/ha were primarily due to improvements in root weight, length, and diameter. However, excessive nitrogen led to more above-ground growth and lower root weight. Similar results were reported by [21], where 80% RDF showed the best yield attributes. [22] also found that root yield increased with N levels up to a point. [23] suggested 80:50:80 NPK kg ha^{-1} for higher root yield and quality. In contrast, [24] observed positive effects of increasing N levels on growth but lower yield attributes, while [15] reported different results.

Table 2: Effect of conservation agriculture practices on root length, root diameter, root weight (g $plant^{-1}$), Projected root yield (t ha^{-1})

Treatment	Root length (cm)	Root diameter (cm)	Root weight (g $plant^{-1}$)	Projected root yield (t ha^{-1})
T_1	16.60	3.25	97.69	23.50
T_2	17.90	3.52	111.30	25.76
T_3	14.70	2.95	88.67	20.11
T_4	17.40	3.43	105.11	24.55
T_5	18.50	3.58	118.37	26.63
T_6	15.80	3.19	92.53	21.00
T_7	13.80	2.76	72.99	15.30
S.Em (±)	**0.24**	**0.07**	**0.42**	**0.71**
C.D(0.05)	**0.73**	**0.22**	**1.32**	**0.54**

Comment [OAPB28]: Showing this results as a bar chart will facilitate their interpretation.

Quality parameters

TSS (ºBrix)

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Different fertilizer levels and mulch treatment significantly influenced the quality of carrot. Among different treatments, total soluble solids followed the similar pattern like projected yield. The data illustrated in the Table. 3 clearly demonstrated that different treatments had significant influence during both the year. Perusal of the pooled data showed that highest TSS (9.18ºBrix) under T_5 (90:60: 90 kg ha^{-1} + berseem) followed by 9.0 ºBrix in T_2 (90:60: 90 kg ha^{-1}). Control recorded lowest TSS (7.87 ºBrix). TSS increased with increasing level of fertilizer upto certain level. Further additional increase in fertilizer dose, decreased the yield and quality [25][26] [27] [28]~~. Similar results were also reported by~~[23].

β-carotene

The data illustrated in the Table.3 clearly demonstrated that different treatments had significant influence on beta carotene during both the year. Perusal of the pooled data showed that highest carotene (4.18 mg 100 g^{-1}) under T_2 (90:60:90 kg ha^{-1}) followed by 4.09 mg 100 g^{-1} in T_5 (90:60:90 kg ha^{-1}+ Berseem). Control recorded lowest β-carotene (3.08 mg 100 g^{-1}). Increasing level of fertilizer resulted in increasedβ-carotene. Further Similar results were also reported by [23][29].

Table 3: Effect of conservation agriculture practices on TSS (ºBrix) and β-carotene

Treatment	TSS (ºBrix)	β-carotene (mg 100 g^{-1})
T_1	8.64	3.83
T_2	9.00	4.18
T_3	8.26	3.60
T_4	8.88	3.82
T_5	9.18	4.09
T_6	8.29	3.57
T_7	7.87	3.08
S.Em (±)	**0.07**	**0.10**
C.D(0.05)	**0.21**	**0.31**

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Comment [OAPB29]: Showing this results as a bar chart will facilitate their interpretation.

CONCLUSION

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The ~~use~~ implementationof conservation agriculture principles, ~~including~~ such asminimal tillage, fertilizer, and mulch, ~~greatly~~ significantlyimproves carrot yields. Minimum tillage preserves soil quality, reducing erosion and weed pressure. Fertilizer supplies crucial nutrients, promoting root development and resulting in higher yields. Mulch maintains soil moisture and temperature, fostering optimal carrot growth. This strategy enhances production and supports sustainable farming practices.

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Comment [OAPB30]: Review the reference style of the journal.

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