Impact of Fertilizer and Mulch on Growth, Yield and Quality of Carrot in Arecanut Cropping System Under Conservation Agriculture Practices

ABSTRACT

This 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. As per the principles of conservation agriculture *i.e.,* soil was disturbed minimally, berseem mulch was incorporated in the experiment and carrot was raised under arecanut plantation during *rabi* and it was succeeded by mint crop in *pre-kharif* season. Experiment was laid out in Randomized block design with seven treatments of different nutrient doses and mulch replicated thrice. Field experiments were conducted across two growing seasons *i.e.,* 2019-20 and 2020-21 during *Rabi* (Winter) at Balindi research farm, Bidhan Chandra KrishiViswavidyalaya, Mohanpur. Precise measurements and meticulous analyses were conducted on key parameters; Vegetative growth i.e., plant height and number of leaves, yield attributing parameters like root length, diameter, weight and total yield of crop. TSS and beta carotene was also estimated. These parameters unequivocally indicate that conservation agriculture practices exert a substantial influence on both the growth and yield. Among various nutrient levels, higher dose of fertilizer (T_4 - 120:90:120 NPK kg ha^{-1}) with berseem (*Trifoliumalexandrinum* L.) 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 (*Trifoliumalexandrinum*) 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. 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.

1. INTRODUCTION

Carrots (*Daucuscarota* L.) are a pivotal component of global agriculture [1], acclaimed for their nutritional value and culinary versatility. It is a cold-weather vegetable belonging to Apiaceae. 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 [2]. Carotenoids are a class of phytochemicals that serve as precursors to vitamin A, making carrots a valuable resource in mitigating the risk of vitamin A deficiency [3]. Furthermore, carrots offer substantial nutritional value, containing significant quantities of essential nutrients such as protein, carbohydrates, dietary fiber, thiamine, riboflavin, iron, calcium, phosphorus, and vitamin C [4]. The cultivation of carrots, like many crops, has traditionally relied on conventional agricultural practices including intensive tillage 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.

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 [5] 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 [6].The integration of carrot cultivation into arecanut based 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.

This research primarily focuses on studying the effect of different levels of fertilizer on growth, yield and quality of carrot crop raised following conservation agriculture principles. The findings hold promise not only for enhancing carrot production but also for promoting sustainable and resilient arecanut-based agro ecosystems, 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.

2. MATERIAL AND METHODS

Field experiment was conducted for two consecutive years *i.e.,* 2019-20 and 2020-21 at Balindi Research Farm, Bidhan Chandra KrishiViswavidyalaya, Nadia, West Bengal located at 22°57’ N 88°32’ E, with an altitude of 9.75 m asl. Topographic situation of the experimental site comes under the well-drained gangetic 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}).

The agricultural approach in this study aligns with the sustainable land management practices. Specifically, in the inter row 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 of the experiment are mentioned in the table below.

Table 1. Treatment details of the experiment

S.No	Treatment details
1	T_1: 120:90:120 NPK kg ha^{-1}
2	T_2: 90:60:90 NPK kg ha^{-1}
3	T_3: 60:45:60 NPK kg ha^{-1}
4	T_4: 120:90:120 NPK kg ha^{-1} + Berseem
5	T_5: 90:60: 90 NPK kg ha^{-1}+ Berseem
6	T_6: 60:45:60 NPK kg ha^{-1}+ Berseem
7	T_7: Control

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 line sowing 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 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 line sowing berseem (*Trifoliumalexandrinum)* 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.

3. RESULTS AND DISCUSSION

3.1 Plant Height

From the experimental results it was confirmed that, the application of a higher dose of fertilizer has a notable impact on vegetative growth (Table 1). At 30 days after sowing (DAS), the 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).

3.2 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).

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 [7]. These factors collectively promote vegetative growth and overall plant development [8] and consistent with findings from [9-14]

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 [15],further promoted plant development. This highlights the importance of nutrient management and mulching for optimal plant growth and agricultural productivity.

3.3 Root Length (cm)

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 followed by 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. [11]in nitrogen and [16] reported that application of 120 kg K_2O ha^{-1} showed statistically identical results with 90 kg K_2O ha^{-1}. [17] also opined that yield components were highest under mulched condition.

3.4 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).

3.5 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).

3.6 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).

Table 2.Effect of fertilizer and mulch on plant height and number of leaves plant^{-1} of carrot under conservation agriculture practices

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

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

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 [18-20]. 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 [21,22]

In this study, reduced tillage significantly increased carrot yield compared to land management practices adopted in conventional agriculture. This agrees with results of previous studies by [23,24] [25].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 [23] Agbede. Carrot performance is notably affected by N and K [26].

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 [27],where 80% RDF showed the best yield attributes. [11] also found that root yield increased with N levels up to a point. [28]suggested 80:50:80 NPK kg ha^{-1} for higher root yield and quality. In contrast, [29]observed positive effects of increasing N levels on growth but lower yield attributes, while [26] reported different results.

3.7 Quality Parameters

3.7.1 TSS (ºBrix)

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 up to certain level. Further additional increase in fertilizer dose, decreased the yield and quality [28,30,31,32,33]

3.7.2 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 [28,34].

Table 3. Effect of fertilizer and mulch on root length, root diameter, root weight (g $plant^{-1}$), projected root yield (t ha^{-1}) of carrot under conservation agriculture practices

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

Table 4. Effect of fertilizer and mulch on TSS (ºBrix) and β-carotene under conservation agriculture practices

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

4. CONCLUSION

The implementation of conservation agriculture principles, such as minimal tillage, fertilizer, and mulch, significantly improves 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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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Stolarczyk J, Janick J. Carrot: History and iconography..Chron Hort. 2011;51:13–18
2. Tanumihardjo SA, Yang Z. Carotenoids: Epidemiology of health effects. In: Caballero B, AllenL, and Prentice A. (eds). Encyclopedia of Human Nutrition. 2nd edn. Oxford, U.K.: Elsevier Ltd.2005;2003:339–345
3. Kopsell DA, Kopsell DE. Accumulation and bioavailability of dietary carotenoids in

vegetable crops. Trends Plant Sci. 2006;11:499–507.
4. Sharma KD, Karki S, Thakur, NS and Attri, S. J. Food Sci. Technol*.* 2011;49:22–32
5. Brouder SM, Gomez-Macpherson H. The impact of conservation agriculture on smallholder agricultural yields: a scoping review of the evidence. AgricEcosyst Environ. 2014;187:11–32.
6. Anonymous. Report of the Committee on doubling farmer's income. Volume II. Status of Farmers income: Strategies for Accelerated Growth. 2017;69-75
7. Maurya KR, Goswami RK. Effects of NPK fertilizers on growth, yield and quality of carrot. Progress. Hortic. 1985;17(3):212-17.
8. Marschner H. Functions of mineral nutrients: micronutrients. In: Mineral Nutrition of Higher Plants. 2nd Ed., Academic Press*,* London. 1995:313-404.
9. Baloch PA, Abro BA, Solangi AH, Siddiqui AA. Growth and yield characteristic of chilli as affected by N in presence and absence of P and K. Pak J Sci Ind.2013;56(2):70-75.
10. Baloch PA, Uddin R, Nizamani FK, Solangi AH, Siddiqui AA. Effect of nitrogen, phosphorus and potassium fertilizers on growth and yield characteristics of Radish (*Raphanussativus* L.), Am.-Eurasian j. agric. environ. sci.2014*;*14(6):565-69.
11. Moniruzzaman M, Akand MH, Hossain MIM, Sarkar D, Ullah A. Effect of nitrogen on the growth and yield of carrot (*Daucuscarota*L.). The Agric: A Sci J of Krishi Foundation*.* 2013;11(1):76-81.
12. El-Tohamy WA, El-Abagy HM, Badr MA, Abou-Hussein SD, Helmy YI. The influence of foliar application of potassium on yield and quality of carrot (*Daucuscarota* L.) plants grown under sandy soil conditions. Aust. J. of Basic Appl. Sci. 2011;5(3):171-74
13. Hossain AKMM, Islam MR, Bari MS, Amin MHA, Kabir MA. Effects of mulching and levels of potassium on growth and yield of carrot. Bangladesh Res. Publ. J.2009;3(2):963-70.
14. El-Bassiouny, RI, EL-Seifi SK, Omar GF. Effect of potassium fertilizer levels on baby carrot growth and storability.J. Agric. Sci. Mansoura University*.* 2003;28(3):2063-97.
15. Yu SL, He JS, Zhang GH. Study on effects of mulching groundnuts with plastic film on soil fertility and activity of the micro flora. J. Soil Sci. 1981;5:30**-**323.
16. Haque MS, Haque AFM, Hossain B, Naher N, Eakram MS. Effect of potassium fertilization to increase the yield of carrot (*Daucuscarota*L.). International Journal of Bioinformatics and Biological Science. 2019;7(1&2):15-19.
17. Rahman MA, Islam MT, Al Mamun MA, Rahman MS, Ashraf MS. Yield and quality performance of carrot under different organic and inorganic nutrient sources with mulching options. Asian Journal of Agricultural and Horticultural Research. 2018;1(4):1-8.
18. Malecka I, Blecharczyk A, Sawinska Z, Dobrzeniecki Z. The effect of various long-term tillage systems on soil properties and spring barley yield. Turk. J. Agric. For. 2012;36:217–26.
19. Celik I, Turgut MM, Acir N. Crop rotation and tillage effects on selected soil physical properties of a TypicHaploxerert in an irrigated semi-arid Mediterranean region. Int. J. Plant Prod. 2012; 6(4):457–80.
20. Acar M, Celik I, Gunal H, Effects of long-term tillage systems on aggregate associated organic carbon in the eastern Mediterranean region of Turkey. Eurasian J. Soil Sci. 2018;7(1):51–58.
21. Blanco-Canqui H, Wienhold BJ, Jin VL, Schmer MR, Kibet LC. Long-term tillage impact on soil hydraulic properties. Soil Tillage Res. 2017;170:38–42.
22. Obour AK, Chen C, Sintim HY, McVay K., Lamb P, Obeng E, et al. *Camelina sativa* as a fallow replacement crop in wheat-based crop production systems in the US Great Plains. Ind. Crop. Prod. 2018;111:22–29.
23. Agbede, T.W. Effect of tillage, biochar, poultry manure and NPK 15-15-15 fertilizer, and their mixture on soil properties, growth and carrot (*Daucuscarota* L.) yield under tropical conditions.Heliyon2021;7(6):e07391
24. Bajkin A, Ponjican O, Zoranovic M. The impact of tillage on physical features and yield of carrot root. J. Process. Energy Agric. 2010;14(4):169–72
25. Brainard DC, Noyes DC. Strip tillage and compost influence carrot quality, yield, and net returns. Hort.science. 2012;47(8):1073–79.
26. Ali MA, Hossain MA, Mondal MF, Farooque AM. Effect of nitrogen and potassium on yield and quality of carrot. Pak. J. Biol. Sci*.* 2003;6(18):1574-77.
27. Patel SM, Amin AU, Patel HB. Effect of spacing and fertility levels on growth and

yield ofcarrot (*Daucuscarrota* L.) cv. GDC 1. Gujarat Agric. Univ. Res. J. 2019;44(4):206-09
28. Lyngdoh GBS. Response of carrot to different levels of nitrogen, phosphorus, and potassium. J. Hortic. Sci. 2001;14:163-69.
29. Wilson H, Persad S, Persad, N. Effects of nitrogen, phosphorus and potassium fertilization on the growth and yield of radish on a Vertisol. Proc. of the Caribbean Food Crops Soc. 2009; 45:16-26
30. Salo T. Nitrogen Budget in Cabbage, Carrot and Onion Production. NJF-utredning/rapport nr. 1996;114:22-27
31. Warncke DD. Soil and Plant Tissue Testing for Nitrogen Management in Carrots. Commun. Soil Sci. Plant Anal. 1996;27:597-605
32. Raynal-Lacroix C. Nitrogen Nutrition of Carrots. Proc. of the Third Congress of the Eur. Soc. for Agrono, Padova, Italy, 1994;616-17.
33. Balvoll G. *Grønsakdyrkning pa friland.Landbruksforlaget*, Oslo, Norway;1995.
34. Rakocevic BL., Pavlovic R, Zdravkovic J, Zdravkovic M, Pavlovic N, Djuric M. Effect of nitrogen fertilization on carrot quality. African Journal of Agricultural Research.2012;7(18):2884-900.