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REVIEW ARTICLE

Optimizing baby corn yield and quality: Insights from organic and agronomic interventions

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Abstract

Cultivation of baby corn, a profitable crop in the global agricultural market, requires careful attention to increase yield, productivity and quality. This review examines the impact of various land configuration practices and organic nutrient management practices on baby corn yield, productivity and quality. Different land configurations, including flat beds, broad beds and ridges and furrows, can be combined with organic nutrient management strategies that utilize various plant and animal-based soil amendments. While organic nutrient management has increased the nutritional content of baby corn, particularly by increasing micronutrient levels, improvements in land configuration have had a substantial influence on the crop's productivity. Physical characteristics, such as cob length, width, grain homogeneity and overall quality, have all been significantly improved. These improvements support sustainable farming practices, in addition to increasing the market value of baby corn. Baby corn's versatility and nutritional advantages have expanded its commercial potential and raised demand for both fresh and processed varieties. This review highlights the importance of integrating organic nutrient management with land configuration to enhance the sustainability, quality and productivity of baby corn farming.This review offers valuable insights for farmers and agricultural professionals, supporting the adoption of integrated approaches that harmonize land management techniques with organic nutrient management to optimize crop performance, ensure environmental sustainability and promote farmers' well-being.

Keywords: agronomic efficiency; environmental sustainability; land configuration; organic nutrient management; sustainable farming

Introduction

Baby corn, also known as mini corn or candle corn, is a stalk of corn that is harvested young when the silks have not yet germinated or have just budded and fertilization has not occurred. It is tender and succulent, with a snap-like crunch, containing a mild, subtly sweet, earthy and vegetal taste. Baby corn is a valuable, short-duration (65-75 days) versatile cereal crop that is well-suited for intensive and diverse cropping systems and as a choice for year-round cultivation in different ecological conditions (1). Baby corn is one of the most important dual purpose crop grown throughout the year in India (2). Marketable cobs are 7-10 cm long and 2-3 cm in diameter and are harvested at 50-55 days after sowing (DAS) (3). The most popular colour for consumers and exporters is usually a shade of yellow, ranging from ream to very light yellow. Because baby corn is a short-duration crop that allows farmers to get the maximum harvest with improved yields, which doubles the income of farmers (4). Baby corn cultivation offers opportunities for crop diversification, value addition and green fodder production. Baby corn is nutritious and has the same or even better nutritional value than some seasonal vegetables. Apart from the main product, it also provides high quality green fodder, a valuable feed for livestock (5). So growing baby corn offers an opportunity to support a dairy farm. Baby corn is not merely a cash crop, but also a catch crop, serving as a contingent crop in the event of crop loss. Baby corn was developed in the late 1970s and is used as a vegetable crop due to its delicious taste and nutritional value, which includes beneficial properties for human health. As a result, demand for baby corn has increased in the market, making it a cash crop (6).

Baby corn is susceptible to both excessive and insufficient moisture stress. Waterlogging decreases soil enzyme function and limits nutrient availability, while drought affects water-use efficiency. Thus, effective land configuration technologies, such as raised beds, ridge and furrow, broad bed furrow and sunken beds, are crucial for managing water efficiently, minimizing crop stress and encouraging uniform growth. These approaches have proven to enhance drainage, aeration and soil structure, ultimately improving crop yield and quality. At the same time, growing health concerns about synthetic fertilizers have led to a greater demand for safe, organically grown produce. Nevertheless, nutrient management continues to be a restricting factor in organic farming. Techniques such as enriched composting, vermicomposting, green manuring and the application of biofertizers are being implemented to enhance nutrient availability, soil fertility and microbial activity. This review is based on the assumption that by adopting land configuration policies and managing organic nutrients, collective efforts can increase yield as well as the quality and sustainability of production for baby corn. To determine the most effective strategies, the methodology involves thoroughly analyzing and summarising findings from relevant field research studies, scientific literature and farm practices. The objective is to promote the creation of productive and sustainable baby corn cultivation systems that address both economic and social concerns, offering practical guidance to researchers, extension professionals and farmers.

Baby corn : current status and prospects

Baby corn can be grown under various climatic and soil conditions. Farmers can cultivate up to four crops a year, creating jobs for the rural poor. In the past, baby corn was a delicacy and its cuisine was in star hotels or fine restaurants (6). Today, baby corn are more readily available in grocery store and can be purchased under the general umbrella (7). Baby corn production has been very successful in countries such as Thailand, Taiwan, Srilanka and Myanmar. The cultivation has also started in countries such as Zambia, Zimbabwe ans South Africa.

At present, Thailand and China are the global leaders in the baby corn production. In India, baby corn is grown in Meghalaya, Western Uttar Pradesh, Haryana, Maharashtra, Karnataka and Andhra Pradesh (8). India's Northeast Himalayan Region (NEHR) is a rainfall region of more than 26.3 Mha with an annual rainfall of 250 cm, which is particularly important for organic baby corn cultivation due to its specialized climatic conditions. Baby corn production and markets are rising globally, exclusively in Asia, Africa and South America. India has been changing its eating habits for years, paving the way for the popularity of baby corn. Therefore, the demand for baby corn is growing rapidly in urban India (Fig. 1). The domestic baby corn market is expanding due to the increase in the number of farmers, which has further increased production and market availability. Due to the information technology revolution, baby corn is gaining popularity in the domestic and foreign market and gaining more processing and export potential (9). In India, the focus is now on exploring its ability to earn foreign exchange, in addition to providing high economic returns to farmers.

Nutrient profile and applications

Due to excellent taste, texture and nutritional benefits, baby corn is expected to become more popular among consumers and farmers. As lifestyles change, the demand for baby corn is increasing due to its nutritional value. It is a low-calorie, low-cholesterol and fibre-rich product. It has a lower glycemic index than regular corn, so baby corn is good for controlling blood sugar. Baby corn contains a lot of folate, vitamin B; four ounces (about 20 servings) provides 31 % of the recommended daily allowance (RDA). One 4 ounce serving also contains 13 % of the potassium, 14 % of vitamin B6, 10 % of riboflavin, 17 % of vitamin C and 11 % of the fiber that adults need each day (10) (Table 1).

Baby corn is a delicious, decorative and nutritious vegetable with zero cholesterol. In terms of minerals, one baby corn can be compared to an one "egg". This vegetable is likely the only one devoid of pesticide residues because it is covered with cob husk and safe for consumption by human beings compared to the other vegetables directly exposed to pesticides (11). It is a nutritious vegetable full of essential vitamins and minerals. Baby corn has a high nutritional value and it is comparable to many expensive vegetables such as

Table 1. Nutritional composition of baby corn per 100g

Nutrient	Per 100 gram	Reference
Calorie	96 g	
Protein	3.4 g	
Carbohydrate	21 g	
Fiber	2.4 g	
Fat	0.08 g	
Phosphorus	0.086 g	
Potassium	0.483 g	
Sodium	0.158 g	
Magnesium	0.076 g	
Iron	0.002 g	
Vitamin A	276 retinol equivalents (RE)	(10)
Vitamin C	0.016 g	
Ascorbic acid	0.011 g	
Sugar	0.016-0.020 %	
Moisture	89.1 %	

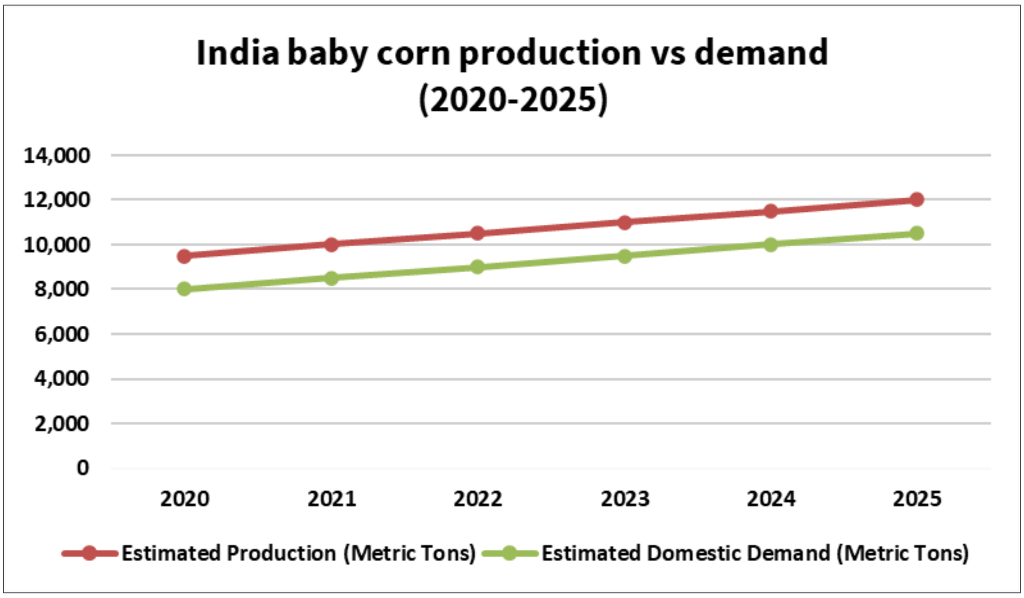

Fig. 1. India baby corn production vs demand.

cauliflower, cabbage, beans, spinach, lady's finger, tomato, radish, etc. (12). Two carotenoids, zeaxanthin and lutein, are present in it. These compounds are known to help prevent cataracts and maintain good eye health. It contains a significant amount of crude fiber and fibrous proteins, which helps to prevent colon cancer.

Baby corn is edible in both raw and cooked forms. It is a key ingredient in many traditional and continental dishes in addition to cans. It is used as an aesthetic crunchy vegetable in salads, soups, pickles, pakodas, vegetables, mixed vegetables, pasta, chutneys, cutlets, dried vegetables, kofta curry, manchurian, raita, sweet, jams, murabbas, burfis, halwa, kheer, fried with baby corn meat and rice and with other favorite foods (13). Baby corn is a popular vegetable in the United States, Europe and Southeast Asia. It is a high-quality organic food that can be used to make a variety of value-added baby corn products. In addition, it is considered as a good forage plant because it is highly nutritious and does not contain antinutritional factors. Compared to other forage crops, baby corn has high fodder productivity, which is rich in energy and soluble carbohydrates. High succulence, palatability and digestibility make baby corn an ideal fodder crop and it can be used at any stage of its growth (14). In addition, solid dry leaves can be used as good fuel. The added value of baby corn enables its availability in off-season and provides job opportunities for people below the poverty line. Additionally, it is beneficial in both the food and feed sectors (15).

Challenges in baby corn cultivation

The development of organic production technology for baby corn is necessary to achieve higher yields and economic benefits with increased soil health (16). Nutrient management in organic baby corn cultivation is a key difficulty for securing higher returns. In organic agriculture, the synchronization of nutrient release and harvest demand is very necessary (17). Therefore, to avoid nutrient stress, it is important to thoroughly understand the pattern of nutrient diffusion from organic sources (18). The supply of organic manure is also a concern in organic nutrition management. Literature for recommended dosage of organic nutrients throughout the baby corn growing season is quite limited and organic production technology in baby corn has only recently begun. The usage of inorganic fertilizers helps to attain maximum production of baby corn, but the usage also increases production costs and is hazardous to environmental health (19, 20). Water and nutrients are the most important economic inputs for optimal baby corn production. Soil organic matter degradation is a significant issue and it has been discovered that the conventional deep inversion threshold contributes to the mineralization of the soil's organic material, leading to its continuous decline (21). Lodging in baby corn is a major issue in productivity and production efficiency. Lodging management in baby corn is critical for sustainable agriculture, because lodging can lead to considerable production losses and quality (22). Lodging can be caused by several conditions, including stem length, climatic conditions and crop growth phases. To prevent lodging in baby corn, agronomic measures, chemical applications and genetic modifications can be used. Agronomic measures, including land configuration, are crucial management methods for preventing lodging. It is vital to do study on land configuration issues and stabilize the configuration for increased production (23). Natural resource conservation techniques (RCT) are used to mitigate these harmful effects and helps to save significant amounts of irrigation water, reduces farming costs in terms of organic baby corn cultivation, increases water and nutrient use efficiency and indirectly mitigating the adverse effects of climate change (24).

The harvest stage is very critical because a one day delay in harvesting the cobs degrades the quality of the cobs and weakens market acceptability. Therefore, it is good to assess the correct size of young ears by sensory test at initial picking and then by visual inspection and pinching of the ear to assess the size of the ear inside the husked pods (25). Other factors affecting optimal baby corn production include poor germination, low rainfall and slow growth during the winter season. Therefore, farmers should be aware of advanced baby corn techniques to address these difficulties. In addition, the quality of the ears is an important criterion when choosing a baby corn variety, because the appearance of the ear first attracts consumers. Resistance to tillering and breakage is another desirable trait for varieties used in baby corn production (6). It is necessary to invest in the development of early maturing profitable hybrids. It is cultivated in very few regions in India, because farmers are unaware of the production packages, economic importance and uses of baby corn. Hence, it was deemed necessary to standardize the production technology of baby corn (26). Baby corn is a perishable commodity, so it cannot be stored outside for longer or transported to distant places. Various techniques such as packaging and low temperature storage must be developed to extend the post harvest shelf life. There is no development of baby corn hybrids and varieties in India (27). Silk appearance and ear size are characteristics for harvesting. Therefore, it is difficult to estimate the exact cob stage for different cultivars (28). Research should focus on organic nutrient management packages to reduce nutrient stress and develop hybrids with tillering resistance, lodging resistance and longer shelf life, thereby reducing post-harvest losses. It is also necessary to standardize the harvesting stage and indices of different cultivars (Fig. 2 & 3).

Significance of land configuration in crop production

The first step towards improving any crop's growth and development is to configure the land. Land configuration, i.e. changing the shape of the soil surface and the seed bed, offers a chance to enable the removal of surplus water and prevent water logging on the soil surface. Land management systems are critical in reducing soil erosion and increasing water usage for crops. Flat bed, rides and furrows, broad bed furrows, etc. are some common land configuration techniques. In terms of yield, cob quality and water use efficiency, Ridge and Furrow configuration was the most efficient, followed by Broad Bed (BBF) and Flat Bed exhibiting the least. This indicates that Ridge and Furrow is the optimal land configuration for maximizing baby corn production.

Land configuration methods significantly influence the growth, yield and quality characteristics of baby corn (6). Various land configuration practices are carried out for baby corn production and their efficiencies are studied. However, most research on land configuration has predominantly focused upon ways to prevent or minimize drought stress in baby corn (29).

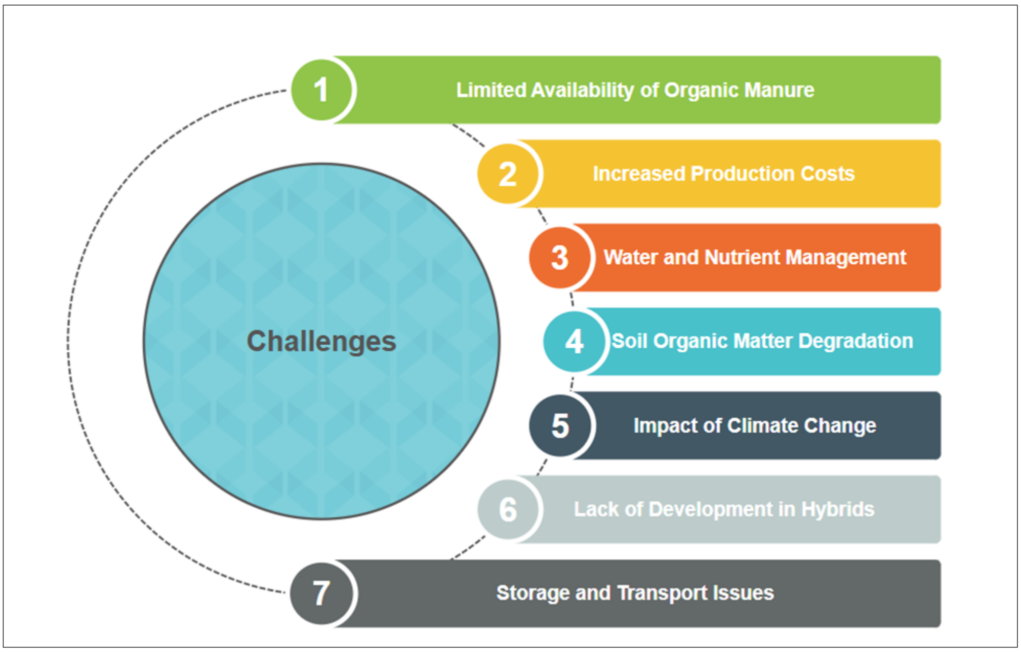

Fig. 2. Challenges of baby corn farmers.

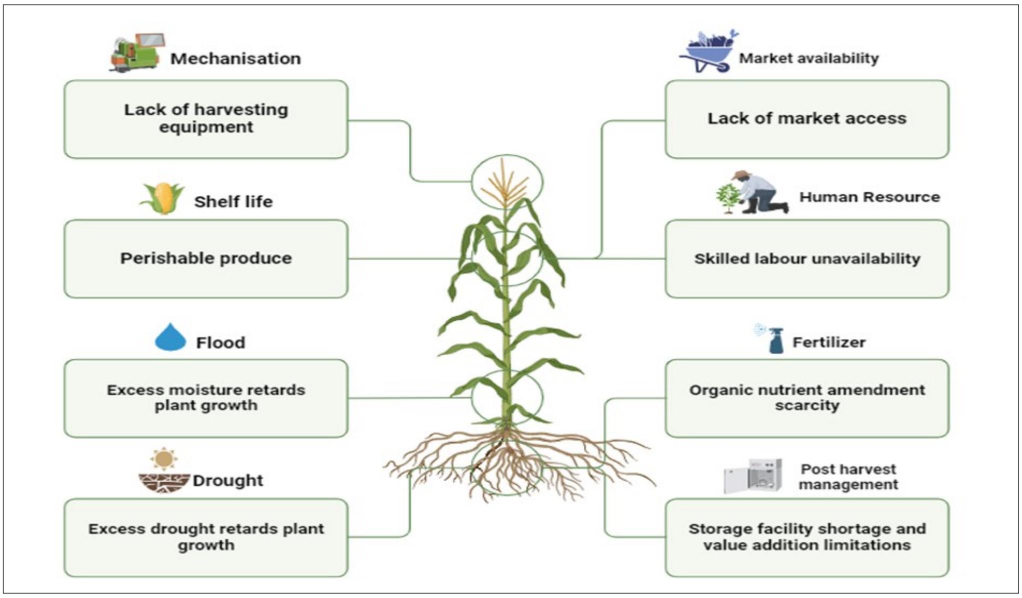

Fig. 3. Different problems endured during baby corn production.

Flat Bed is the conventional land configuration where the entire field surface is leveled uniformly after 2-3 deep ploughings with a spade, without raised beds or furrows (Fig. 4). In an experiment conducted to evaluate the germination and yield of a cotton-maize cropping system, it was concluded that planting with furrow irrigation and conventional tillage resulted in higher germination percentages and yields compared to zero tillage with a flat surface planting system (30).

Ridges and Furrows represent a land configuration in which alternate furrows are created between rows by excavating soil and placing it along the adjacent ridges, enhancing drainage and root zone aeration (Fig. 4). Therefore, 15 cm deep furrows were formed. Maize growth has been studied using different planting methods, namely flat bed and modified bed (ridges and furrows). It was found that the ridge and furrow method significantly increased maize production in terms of plant height and effective number of tillers per plant (31, 32). When pearl millet was sown under ridges and furrows, higher length and girth of the ear head and test weight were observed, which is due to the better growth of the plant in terms of accumulation of dry matter. Due to drainage, soil environment, ventilation, root development, optimal moisture-air equillibrium during plant growth and supplying plants with available nutrients resulted in better growth and development, a cumulative effect ultimately reflected in better grain and stover yield (33). The effect of land configuration in maize found that mean total dry matter yield was significantly higher with ridges and furrow land configuration than flat bed (34). Ridge and furrow planting patterns can effectively improve the microenvironment and ultimately increase the corn grain yield (35). Compared with the conventional planting, ridges and furrow increased plant height but reduced stem diameter and dry matter production. The maximum grain yield (6573 kg/ha) and water use efficiency (WUE) (23.0 kg/mm ha) were obtained from ridges and furrow, which were increased by 15.9 % and 33.9 % compared with conventional planting. Irrigation efficiency and irrigation water use efficiency (IWUE) under the ridges and furrow system improved compared to conventional planting, which was mainly due to the lower volume of irrigation water under the ridges and furrow system (36).

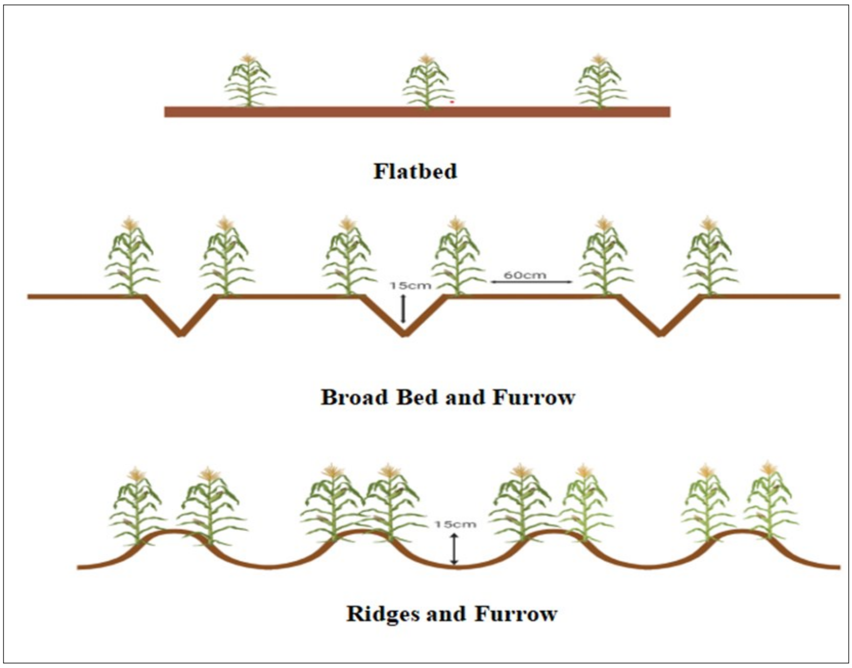

Fig. 4. Land configuration types.

Bed Furrow (BBF) consists of 60 cm wide raised beds with 15 cm deep furrows between them. Two rows of baby corn are planted per bed (Fig. 4). The total furrow width was 20 cm from the edge, two rows of baby corn were sown in a 40 cm × 15 cm bed (6). Notably higher maize grain and stover yield (6692 kg/ha and 8490 kg/ha respectively) and higher plant height, number of leaves, leaf area and leaf area index were observed with BBF at 60, 90 DAS and at harvest compared to flat bed (37, 38). The rise in maize grain yield potentially due to higher soil moisture available for crop growth during the growing season, which may have been projected in higher growth parameters of different crop (39). BBF increased infiltration of rainwater and helped improve moisture storage in the soil profile (40). Further maximum number of cobs (1.40), cob length (21.9 cm), cob width (13.3 cm), grain rows per cob (15.0), number of grains per row (40.4) and 100 seed weight (27.0 g) in maize was recorded under BBF (41, 42).

Impact of land configuration on baby corn production

Influence of land configuration on soil health of baby corn

Land configuration plays a crucial role in determining soil health by influencing erosion, drainage, microclimate, soil structure and biodiversity. Effective land management practices are crucial for maintaining and enhancing soil health, which is essential for sustainable agriculture and ecosystem health. Land configurations significantly influenced the soil microbial biomass carbon (MBC), dehydrogenase activity (DHA), fluorescein diacetate activity (FDA) and acid phosphatase activities. BBF planting method had the maximum soil microbial biomass carbon (374.5 µg MBC/g soil), dehydrogenase activity (21.5 µg TPF/g soil/h), fluorescein diacetate activity (62.3 µg FDA/g soil/h) and acid phosphatase (3.32 µg p-nitrophenol/g soil/h) followed by the ridges and furrow. However, the flatbed had the lowest soil microbial biomass carbon, dehydrogenase activity, fluorescein diacetate activity and acid phosphatase activity (6) (Table 2).

Influence of land configuration on growth and physiological parameters of baby corn

Land configuration is important in shaping crop growth and physiology, as it influences factors such as sunlight, temperature, water availability, soil properties, microclimate and pest pressure. Land management practices optimizes crop growth and maximizes yield. The tallest plants with more leaves were measured at a raised bed height of 50 cm, while the lowest plants with fewer leaves were measured at a raised bed height of 20 cm. This may be due to the detrimental effect of high humidity above the 20 cm humidity level (9). Baby corn on BBF produced the tallest plant of 149.25 cm, maximum leaf area index of 3.5, dry matter production of 64.33 g/plant, cob length of 8.10 cm, girth of 6.13 cm and weight of 8.14 g (6) (Table 2).

Influence of land configuration on yield parameters of baby corn

Land configuration is a key factor in determining the yield parameters of crops. Maximum baby corn, green fodder yield and nitrogen uptake were recorded in paired row sowing on BBF (43). In baby corn, corn yield significantly increased as the height of the raised bed increased; the peak yield was 1283.1 kg/ha when the bed was raised to a height of 50 cm (9). Ridges and furrows and BBF yielded maximum baby corn yield over flat bed. However, BBF has set the maximum yield of green fodder over flat bed. Baby corn grown on BBF gave the maximum gross return ($1646.5/ha), net return ($ 906.1/ha) and benefit cost ratio (2.21) followed by ridges and furrow and the lowest net return ($ 567.6/ha) was obtained under flat bed (6) (Table 2).

Organic nutrition significance in crop production

In former times, organic amendments (organic wastes) was the key source of plant nutrients, especially nitrogen. Their application enables better management of often limited resources to combat soil changes resulting from major crop production practices (45) (Table 3). Organic amendments provide macro and micronutrients to restore soil physical and chemical properties (46).

Table 2. Impact of land configuration in baby corn

Land configuration	Impact	Reference
BBF	Maximum baby corn, green fodder yield, nitrogen uptake and net return	(43)
Flat bed	Maximum benefit cost ratio and functional leaves	
Ridges and furrow	Higher green and dry fodder yield	(44)
Raised bed	Taller plants with more number of leaves, maximum baby corn and fodder yield	(9)
BBF	Taller plants, maximum dry matter production, highest leaf area index, maximum cob length, cob girth, cob weight and mineral composition	(6)
Raised bed	Higher yield, green fodder and mean net return	(3)

A soil amendment is any substance added to soil that improves its physical and chemical properties (47). On clay soils, soil amendments improve soil aggregation, increase porosity and permeability and improve aeration, drainage and rooting depth. On sandy soil, soil amendments increase water and nutrient retention capacity (Table 3). Various products are available for soil cultivation in bags or in bulk (48). They can be used at higher speeds, improving the soil more effectively (49). The following are the important soil amendments (Fig. 5 & 6).

Following the Green Revolution, the use of chemical fertilizers increased to achieve maximum crop yields; however, this had significant negative effects on the environment, as well as human and animal health. The negative impacts are : continuous application of synthetic fertilizers can lead to soil degradation and reduced soil fertility over time, Excessive usage can result in nutrient runoff and leaching into water bodies, leading to water pollution, it contribute to air pollution through the release of nitrogen oxides (NOx) and ammonia (NH_3) during fertilizer application and subsequent volatilization, prolonged exposure to certain fertilizers and pesticides has been associated with various health issues, including respiratory problems, neurological disorders and certain types of cancer and intensive usage can disrupt natural ecosystems and reduce biodiversity, the production and use of chemical fertilizers are associated with greenhouse gas emissions, which leads to climate change (Fig. 7).

New practices and methods are sorely needed to increase yields while preserving or maintaining environmental health (60). Organic agriculture is a natural method of cultivation that utilises ecologically sound fertilisation, such as FYM, green manure and compost, as well as biological control methods like biopesticides or herbal agents, including limonoids and nimbecidine (61).

However, the productivity in organic nutrient management depends to a large extent on the guaranteed supply of nutrients through organic fertilizer. Basal application of FYM is insufficient to meet plant nutrient requirements from sowing to harvest due to its low nutritional value and gradual release pattern. This makes synchronizing nutrient release and crop uptake very difficult, especially for short duration crops such as baby corn. The significantly higher yield of baby corn, number of cob per plant, cob length and dry weight showed a similar improvement in baby corn production components due to organic nutrients (62). Organically grown baby corn is competitive in the market because the consumers like freshness, good appearance and taste, which reflect the biochemical characteristics of the products (1). Given the consumer demand, organic products are likely to command a 25-30 % higher price. This compensates for the yield loss and higher cultivation costs of organic corn production and provides more net income and benefit cost ratio (63). The adoption of organic nutrient management lowers the cost of farming and thus increases the financial stability of farmers by receiving a better price from the market (64). The advantages of

Table 3. Impact of various soil amendments

Source	Amendment	Composition			Impact	Reference
		N %	P %	K %		
Plant	Compost	0.5 - 2.5	0.3 - 1.5	0.5 - 1.5	Improves the soil physical, chemical and biological characteristics, soil organic matter and nutrient status	(50)
	Vermicompost	1.5 - 3.0	1.0 - 2.0	1.5 - 2.4	Increases germination, growth and enhances the development of different plant species	(51)
	Green manure	2.0 - 3.5	0.3 - 1.0	1.5 - 2.5	Enhances soil organic matter, soil structure, fertility, nutrient content, microbial biomass, water holding capacity, balancing the soil carbon to nitrogen (C:N) ratio and fertilizer use efficiency	(52)
	Cover crop	1.5 - 3.0	0.5 - 1.0	1.5 - 2.0	Important soil conservation practices and enhances soil health	(53)
	Biochar	0.2 - 1.0	0.5 - 1.5	0.5 - 2.5	Improves soil chemical, physical and biological properties, crop productivity and acts as a remediation tool in soil to adsorb both organic and inorganic contaminants	(54)
Animal	Farm yard manure (FYM)	0.5 - 1.0	0.2 - 0.5	0.5 - 0.9	Enhances plant height, stem diameter, leaf area index, number of pods per plant and seed yield	(55)
	Poultry manure	1.5 - 3.0	1.0 - 2.5	1.5 - 2.0	Increases soil organic matter, soil and leaf N, P, K, Ca and Mg concentrations, plant height, leaf area, stem girth and grain yield	(56)
	Bone meal	3.0 - 4.0	15 - 27	0 - 1.0	Improves the yield, growth and photosynthetic pigments	(57)
	Blood meal	12 - 15	12 - 15	12 - 15	Provides nitrogen source together with the capability to keep the Fe bound to porphyrin organic compounds makes it a good candidate to be used as Fe fertilizer in organic farming	(58)
	Fish waste	4.0 - 6.0 %	2.0 - 4.0 %	0.5 - 1.0 %	Increase of organic carbon, available phosphorus, potassium, calcium and increase of microbiota of soil	(59)

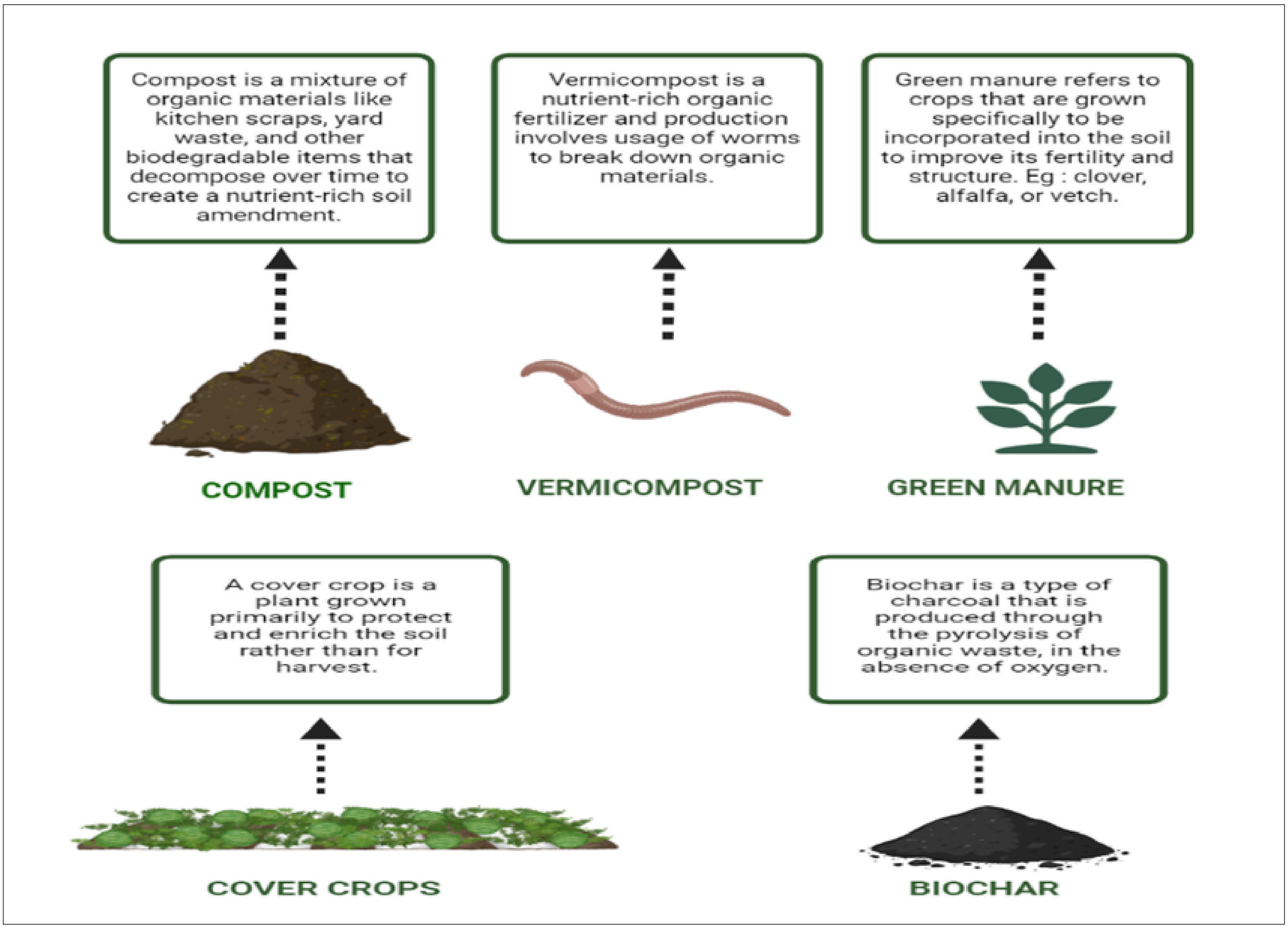

Fig. 5. Plant based soil amendments.

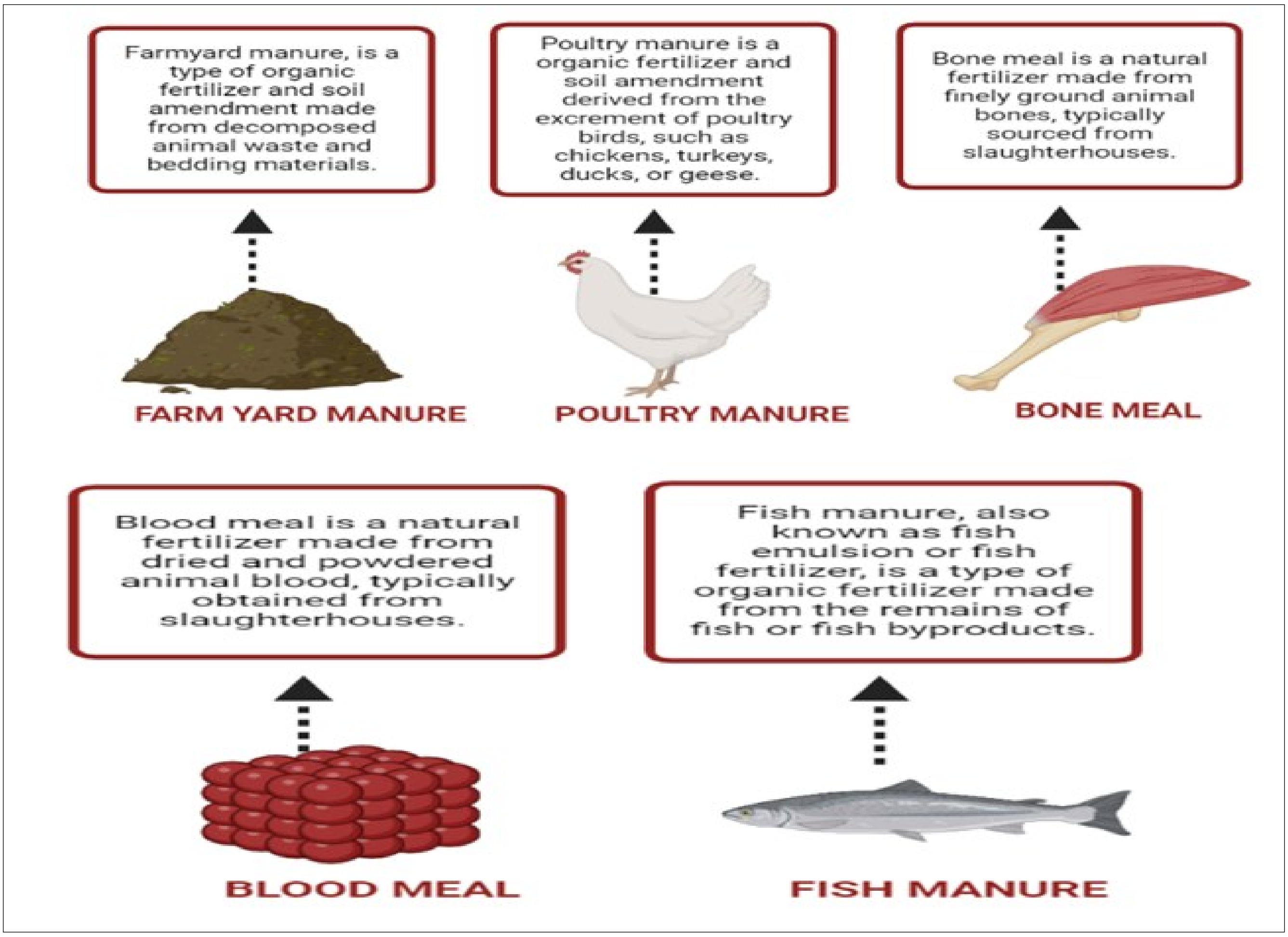

Fig. 6. Animal-based soil amendments.

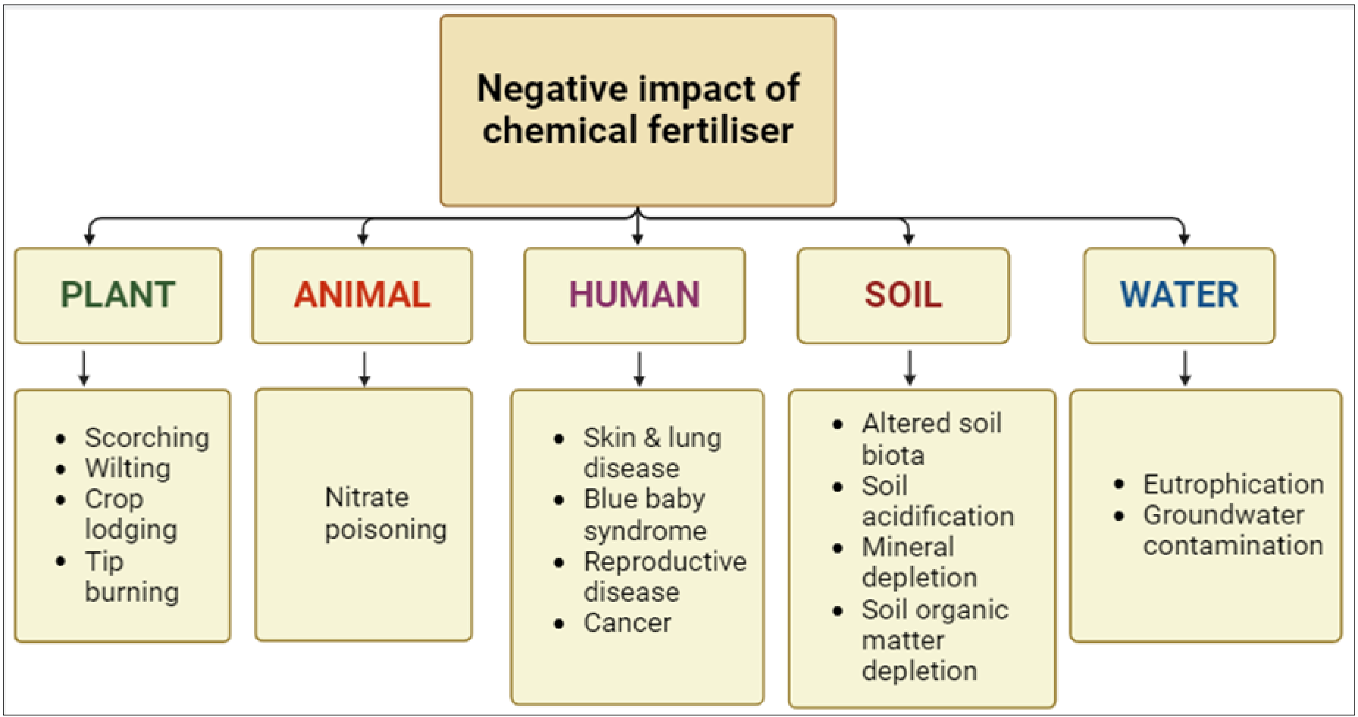

Fig. 7. Negative impact of usage of chemical fertilizer on soil, water, plant, animal and human.

organic baby corn production are much greater than those of conventional production (65). Developing the technology of organic production of baby corn is necessary to achieve higher yields and economic benefits (66).

Impact of organic nutrient management on baby corn production

Influence of organic nutrient management practices on soil health of baby corn

Organic nutrient management practices play a crucial role in enhancing soil health by increasing soil organic matter, improving soil structure, promoting nutrient cycling, balancing soil pH and reducing soil erosion. Adopting sustainable organic farming practices helps improve soil fertility, sustainability and productivity while minimizing environmental impact. Absorption of available NPK was found to be significantly higher when 50 % of the recommended dose of fertilizer was combined with either poultry manure or FYM compared to sole application of 100 % of the recommended dose of fertilizer (67). The application of 180 N + 38.7 P_2O_5 + 74.7 K_2O kg/ha and 50 % N supplied through FYM resulted in a significant increase in available NPK in soil after harvesting baby corn (14). The organic acid produced in the decomposition process of organic manure releases the intrinsic nutrients into the soil and heightens their availability to plants (68). Combining 75 % NPK and 4500 kg/ha of FYM with biofertilizer (Phosphate Solubilizing Bacteria (PSB) + Azotobacter) improved soil physical and chemical properties (69). Continuous application of FYM improves the availability of soil NPK status after baby corn harvest (25). Soil organic matter and available nutrient in the soil were increased by either 25 or 50 %, with FYM replacing N application (8). Combined application 6000 kg/ha of FYM and 2000 kg/ha of vermicompost resulted in the highest soil microbial biomass carbon (377.4 µg Microbial Biomass Carbon/ g soil) (6) (Table 4).

Influence of organic nutrient management practices on growth and physiological parameters of baby corn

Organic nutrient management practices influences the growth and physiological parameters of crops by improving nutrient availability, enhancing soil structure, promoting stress tolerance, stimulating root development and ensuring balanced plant nutrition. Organic farming practices promote sustainable crop production and environmental protection. 150 % recommended dose of fertilizer (225 N : 90 P_2O_5 : 60 K_2O kg ha) and 5000 kg/ha FYM recorded higher plant height in field trial (70). Application of 75 % NPK and FYM 4500 kg/ha and biofertilizer boosted plant height, leaf area index and dry matter accumulation (69). Combined application of 75 % NPK, 4500 kg/ha of FYM and biofertilizer (Azotobacter and PSB) significantly increased various other growth parameters such as plant height, leaf area index, dry matter, crop growth rate and relative growth rate (69). Integrated 5000 kg/ha FYM and 100 kg inorganic N/ha increased growth characters like plant height, number of leaves per plant, leaf area index (LAI) and dry matter accumulation as compared to other nutrient management treatments. This may be due to the improved soil physico-chemical properties such as pH, bulk density, infiltration rate, optimal availability of nutrients and organic carbon, as well as synchronized nutrient release during the growing season which improves soil fertility and nutrient use efficiency, resulting in increased plant height, leaf number, leaf area and dry matter accumulation (71). The effect of integrated nutrient management on baby corn with 75 % NPK and 2250 kg/ha vermicompost applied along with biofertilizer resulted maximum plant height and dry matter accumulation (25). A field trial at Coimbatore found that 50 % NPK integrated nutrient management with poultry manure and biofertilizers (Azospirillum and phosphobacteria) resulted in taller plants (183.1cm), higher LAI (3.47) and dry matter per plant (7543 kg/ ha) (25). A field trial conducted at Tamil Nadu Agricultural University (TNAU), Coimbatore, to evaluate the effectiveness of different organic farming packages showed that a combination of both organics and inorganics, in equal parts of N equivalent, resulted in a higher baby corn yield (8) (Table 4).

Influence of organic nutrient management practices on yield parameters of baby corn

Organic nutrient management practices enhance soil fertility, improve soil structure, promote stress tolerance, support beneficial soil microorganisms and foster long-term sustainability, all of which contribute to higher crop yields and improved yield parameters. The TNAU baby corn field trial involved the use of poultry or goat manure and Azospirillum and phosbacteria, which improved yield by 50 % in the experimental field (67). The combined application of 50 % NPK, poultry manure and Azospirillum + phosphobacteria and 50 % NPK, goat manure and Azospirillum + phosphobacteria resulted in higher baby corn and fodder yields (72). 150 : 75 : 40 kg NPK /hawith 25 kg $ZnSO_4$, 10 kg $FeSO_4$ and 35 kg vermicompost in baby corn-chickpea cropping system resulted in significantly maximum yield (6440 kg/ha) and green fodder yield (23230 kg/ha) over sole application of inorganic sources (14). The combined application of FYM at 6000 kg/ha and 150 % recommended dose of fertilizer (225 N : 90 P_2O_5 : 60 K_2O kg/ha) resulted in maximum cob yield of 2060 kg/ha associated with maximum number of cobs per plot (70). There is a rise in baby corn fodder yield with a gradual rise in nitrogen application (73). The use of enriched compost 2500 kg/ha achieved a significantly better result in terms of cob yield, corn yield, green fodder yield and NPK uptake (26). This can be due to the higher nitrogen content of the enriched compost used. The findings report that increased N application was reported to increase the yield of baby corn (74, 75). The combined application of FYM of 6000 kg/ha and vermicompost of 2000 kg/ha boosted crop growth and yielded 117.8 % higher baby corn yield and 99.7 % higher fodder yield (6) (Table 4).

Influence of organic nutrient management practices on economics of baby corn cultivation

Organic nutrient management practices may involve higher initial costs but provide long-term economic benefits, such as higher prices, market access, environmental sustainability and government support. Adopting organic farming practices helps improve financial sustainability, increase demand for organic products and promote environmental protection. According to a field trial in Kashmir, application of FYM at 6000 kg/ha with 150 % recommended dose of fertilizer of 90 N: 60 P_2O_5 : 40 K_2O kg/ha achieved the maximum benefit cost ratio (70). Integrated nutrient management significantly improved net return (Rs.26815/ha) and benefit : cost ratio (2.83) (25). Combined use of FYM of 6000 kg/ha and vermicompost of 2000 kg/ha results in elevated gross return (1746.9 $/ha), net return (935.8$/ha) and benefit cost ratio (2.15) (6). A trial conducted at the Indian Statistical Institute, Kolkata, resulted in a higher benefit-cost ratio with the combined application of a recommended dose of fertiliser (50 % 150 N : 60 P_2O_5 : 60 K_2O kg/ha), Arbuscular mycorrhiza and Azospirillum (76). In the cultivation of baby corn (*Zea mays* L.), using 50 % nitrogen through enhanced farmyard manure (FYM) with neem cake and bio compost resulted in higher net returns (78) (Table 4).

Unexplored areas in current research

- The structure and nutrient dynamics of soil can be significantly influenced by various land configuration techniques such as raised beds and contour farming (81). However, the specific interactions between land configurations and organic amendments in baby corn cultivation remain underexplored.
- Efficient water use is crucial, particularly in organic farming systems, where nutrient management differs significantly from conventional approaches. Research on land configurations has demonstrated improvements in water use efficiency across various systems (64).
- There is a need for further investigation into integrated approaches that combine land configuration and irrigation techniques to optimise water use in baby corn cultivation.
- There is a lack of longitudinal studies assessing the impact of combined practices (land configuration + organic amendments) on soil health and yield stability over multiple seasons. A long-term research trial combining land configuration and organic nutrient management has been initiated (64), highlighting the growing importance of such

Table 4. Impact of organic nutrient management in baby corn yield and quality

Soil amendment + Dosage	Impact	Reference
FYM (6 t/ha)	Increased yield, green fodder and total soluble sugar	(70)
Vermicompost (1.92 kg/bed) + Biospirillum (10 mL/kg of seed) + Biophos (10 mL/kg of seed) + biopotash (10 mL/kg of seed)	Higher corn yield	(77)
50 % N as Enriched FYM + neem cake + bio compost	Higher yield and net return	(78)
FYM (6000 kg/ha) + vermicompost (2000 kg/ha)	Higher fodder yield and improved cob quality	(6)
Enriched compost (2500 kg/ha)	Higher cob yield, green fodder yield, N, P, K content and uptake	(26)
Paddy straw mulch (2000 kg/ha)	Higher cob yield, green fodder yield, nutrient content and uptake	
FYM (50 kg N eq./ha) + vermicompost (50 kg N eq./ha) + Enriched biodigested liquid maure (50 kg N eq./ha) + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray (3 %) at 30 DAS	Improved quality parameters : total soluble solids, moisture, crude protein, crude fibre and higher baby corn yield	(79)
100 % recommended dose of nitrogen through paddy husk ash (PAH)	Higher corn yield and green fodder	(80)
100 % RDN through potato peel compost	Higher N concentrations in baby corn cob and green fodder	

integrated systems. Further research is essential to confirm the long-term benefits of combining land configuration with organic nutrient management strategies.

- Investing in such integrated approaches is crucial for the sustainable intensification of baby corn systems, potentially increasing productivity, enhancing environmental health and ensuring economic viability (Fig. 8). This strategy provides a holistic path toward sustainability, benefiting both farmers and consumers in the long run (77).

Future Prospects

Baby corn is emerging as one of the most important crops in developing countries. There are huge opportunities in organic contract farming of baby corn to ensure guaranteed income for farmers (82). Systematic efforts are needed to develop specific genotypes with desired morphological and quality characteristics (83). Developing site-specific and cost-effective integrated nutrient management practices to reduce dependence on chemical fertilizers is essential (84). Genotypes suitable for canning should be advanced so that baby corn continues to be grown for marketing and export. It is also necessary to promote entrepreneurship and establish appropriate storage and distribution facilities (6). Many food processing companies are developing in the Northeastern Himalayan Region (28) and the baby corn canning and pickling industry has significant export potential. Baby corn can be grown throughout the year and the cost of production in India is the lowest in the world. Thus, India has the potential to become one of the largest producers. This crop guarantees year-round employment, particularly for the rural poor, as three to four crops can be cultivated annually. It creates jobs in cultivation, marketing, processing and exporting (82).

The international market values baby corn for its freshness, flavor, health benefits, pesticide-free quality and diverse culinary uses. Given the high demand for quality produce, baby corn has great potential to earn foreign exchange (10). As a highly nutritious vegetable, rich in protein, vitamins, iron, fiber and phosphorus, it addresses both nutritional and food safety concerns. It also serves as an ideal crop for diversification, especially in rice-wheat systems and is well-suited for urban agriculture (68). Its cultivation not only boosts farmer income but also contributes to maintaining soil health. Additionally, the promotion of the baby corn industry requires regional cooperation for germplasm exchange, hybrid testing, joint visits, human resource development, research collaboration and sensitizing policymakers to suitable production and processing technologies. Global research support and effective policy-making are crucial to unlocking the full benefits of baby corn. Policies should focus on engaging young farmers and encouraging both public and private sector participation (85).

Land configuration studies help determine the most effective planting layout, significantly influencing plant growth, soil properties and crop yield. Understanding the effects of various configurations provides insights into soil health and nutrient management for sustainable baby corn production (86). Organic nutrient management plays a crucial role in boosting production, economic returns and sustainability. Studies show that integrating organic and inorganic nutrients enhances crop performance and profitability (86). Combining land configuration and organic nutrient management offers practical advantages by enhancing productivity, improving water-use efficiency and promoting soil health. Techniques like land shaping and the application of organic inputs enhance drainage, moisture retention and natural pest control. These strategies reduce chemical input dependency and foster more resilient agroecosystems. Their affordability makes them accessible to smallholders, improving soil fertility and reducing erosion. Community-based collaboration can further promote the adoption of sustainable practices, enhancing both environmental sustainability and economic viability.

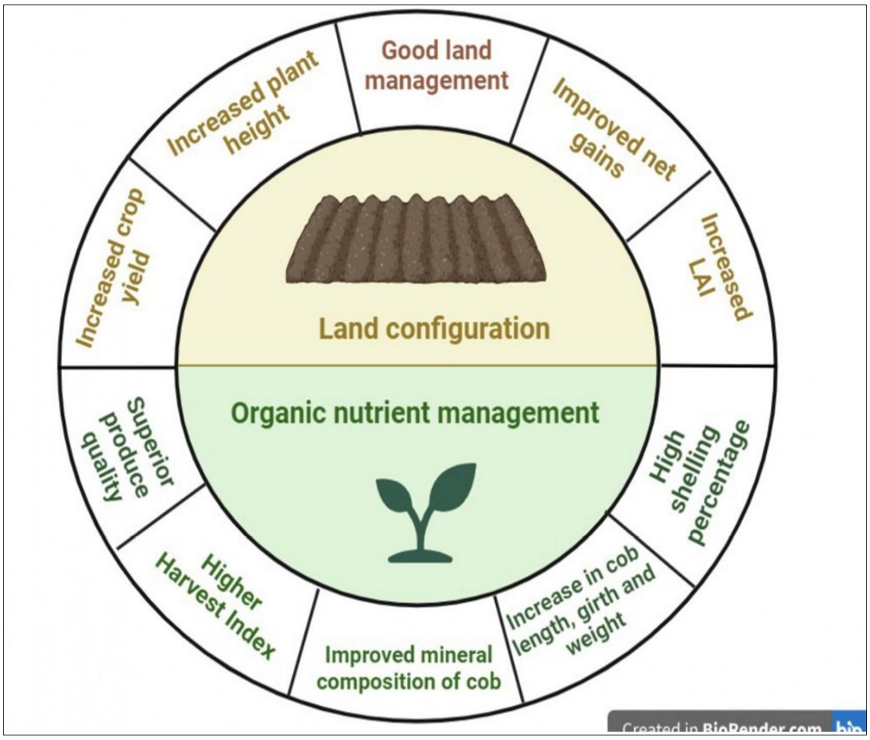

Fig. 8. Impact of land configuration and organic nutrient management in baby corn yield and quality.

Conclusion

Proper land configuration plays a vital role in the successful farming of baby corn. Farmers should consider soil type, drainage, slope and sunlight to ensure suitable water application, preventing soil erosion and providing the right conditions for growing healthy, resilient plants. A suitable land configuration ensures the better use of inputs, improved overall farm efficiency, more sustainable production, increased farm yields and long-lasting farm productivity.

Organically managing the supply of nutrients is important to improving soil health and crop productivity. Organic fertilizers, compost and other natural inputs can be used to build soil quality, while also causing less harm to the environment and promoting sustainable agricultural practices. While organic farming produces healthier crops, it also supports a more sustainable ecosystem and food system. Organic baby corn is particularly valuable to purchasers, offering a pesticide-free and healthier alternative to conventionally grown crops. The requirements of organic farming methods provide farmers with an opportunity to earn better economic returns on their investments. As demand for organic products continues to rise, both in domestic and international markets, farmers will have access to higher-value markets and earn better prices for their products. The essentials of sustainable agriculture include maintaining soil integrity, effective use of water resources and promoting increased biodiversity. The practice of sustainable agriculture reduces chemical use and preserves natural resources for future generations to produce food, as well as social and economic opportunities. Sustainable agriculture provides a financial and social opportunities for the future.

Advancements in technology for baby corn cultivaors can include land configuration measures for baby corn production, direct and indirect faster production methods, more organic fertilizers and environmentally sound agricultural cultivation practices. These improvements will enable farmers to increase productivity and reduce input costs, leading to improved sustainability and benefits for agriculture and the environment. By integrating these comprehensive improvements, India has the potential to become a global leader in organic baby corn production. This would not only boost the country's economy but also enhance the health and well-being of its people, while ensuring a sustainable and enjoyable planet for future generations.

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Authors' contributions

AR prepared the initial draft of the manuscript. SPM reviewed the manuscript and suggested critical improvements. VSV provided input on the manuscript structure and contributed to refining its content. KP assisted in improving the clarity and coherence of the manuscript during the review. SK guided the writing process and provided technical suggestions. VAGV thoroughly reviewed the manuscript and offered guidance on improving its overall quality. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used the Paraphrasing AI tool and Grammarly to improve language and readability, exercising caution. After using the tool SPM, VSV and AR reviewed and edited the content as needed and take full responsibility for the content of the publication. Authors used Biorender to create images.

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