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Research Article

Comparative evaluation of strawberry cultivars under Subhash Palekar natural farming and conventional farming regimes in Doaba region of Punjab conditions

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Abstract
Natural farming, a recent agricultural innovation emphasizing minimal inputs, helps boost crop production. While strawberries are conventionally cultivated, their natural farming potential remains untapped. In this regard, an experiment was conducted to evaluate the influence of Subhash Palekar natural farming (SPNF) and conventional farming (CF) systems on the vegetative growth and yield performances of five different strawberry cultivars viz. Capri, Winter Star, Winter Dawn, Camarosa, and Nabila under field trials in the Doaba region of Punjab conditions. The experiment included ten treatments and was laid out in the factorial randomized block design employing five distinct strawberry cultivars (Capri, Winter Star, Winter Dawn, Camarosa, and Nabila) as factor I, and farming techniques - SPNF and CF - as factor II. The results confirmed the supremacy of CF for vegetative growth and SPNF system for yield and yield attributing characters. Under the CF, cultivar Capri greatly outgrew other cultivars in terms of increased plant height (5.60 and 12.10 cm) and plant spread (14.87 and 23.63 cm EW; 13.00 and 24.59 cm NS) at 45 and 90 DAP, respectively. Contrarily, under the same farming method, the cultivar Camarosa displayed larger numbers of trifoliate leaves (4.80 and 14.50 at 45 and 90 DAP, respectively), chlorophyll index (56.90 SPAD), leaf area (45.84 cm^2), and stem girth (2.45 cm). However, cultivar Capri produced the maximum fruits per plant (26.14) and yield per plant (328.53 g), while cultivar Camarosa resulted in the maximum average berry weight (16.53 g) and the greater yield efficiency (0.77 kg/cm^2) under the SPNF technique.

Keywords: Conventional farming (CF), Subhash Palekar natural farming (SPNF), Strawberry cultivars, Vegetative growth, Yield

INTRODUCTION

As a delicate fruit plant, strawberries are profoundly influenced by environmental variables, particularly temperature, photoperiod, and soil conditions (Krüger *et al*., 2012; Bradford *et al*., 2010; Kadir *et al*., 2006). It thrives in temperate regions but can also be grown in controlled environments in tropical and subtropical regions using hydroponics or greenhouse systems, extending their production season beyond the conventional growing period (Hydroponic, 2012 and Ahn *et al*., 2021). Key agronomic practices in strawberry cultivation include proper site selection, soil preparation, and nutrient management. These practices aim to optimize growth, flower induction, fruit set, and fruit development (Anttonen, 2006). Additionally, pest and disease management are critical aspects, considering the susceptibility of strawberries to various pathogens and pests (Yan *et al*., 2021). Modern cultivation practices often involve adopting precision agriculture techniques, including using sensors, IoT devices, and data analytics to monitor and optimize crop performance (Triantafyllou *et al*., 2019). This approach enhances resource efficiency, reduces environmental impact, and improves overall productivity, but these techniques demand a higher level of skill and are not practical or economical for every farmer (Zheng *et al*., 2021). Although conventional farming methods played a pivotal role in elevating agriculture in India, shifting it from a state of food scarcity to one of surplus, it has additionally led to many problems, including diminishing factor productivity, dwindling natural resources, a lack of water and nutrients, and negative effects on both climate change and human health (Bharucha *et al*., 2020; Bhattacharyya *et al*., 2020 and Kitamura *et al*., 2021).

Strawberries are a potential supplier of minerals and vitamins (Li *et al*., 2020), and their organoleptic qualities make them particularly appealing to consumers (Predieri *et al*., 2021) . Consumer preferences for fruit intake are largely influenced by the general flavor of the berries, which is subjected to the amounts of organic acids and reducing sugars present in the fruit (Leonardou *et al*., 2021) . Crop management practices play a key role in determining the quality of strawberries, and it is crucial to address the potential risk associated with the accumulation of nitrates, which have been identified as a possible risk to human health (Vorovka *et al*., 2020) . The acceptable daily intake (ADI) of nitrates for an adult weighing 60 kg is set at 222 mg, according to the Scientific Panel on Contaminants in the Food Chain (2008). Therefore, it is important to give special consideration to mitigating nitrate buildup in the edible parts of the plant by carefully selecting appropriate farming techniques, ensuring both food safety and profitable production (Chávez□Dulanto *et al*., 2021).

Climate change-related resource depletion and the heavy use of enhancers (pesticides, fertilizers, and water) underscore the necessity of shifting from conventional farming, which prioritizes profit and production maximization, to a farming model that emphasizes three key performance indicators: climate impact, economic stability, and social stability. Additionally, people are developing greater distrust in the food safety industry, and the legitimacy of conventional farming is being questioned (Cristache *et al*., 2019). Natural farming practices involving holistic cultivation practices are gaining importance and consumer demands. Several natural farming management approaches have been developed, including practices like minimized tillage, intercropping, mulching with plant residues, crop rotation, and the application of microbe-rich concoctions. Additionally, refraining from the use of agrochemicals and biofertilizers is emphasized as part of these techniques (Liao *et al*., 2019).

Subhash Palekar Natural Farming (SPNF), formerly prevalent by the name of Zero Budget Natural Farming (ZBNF), is part of a larger farming culture in India known as natural farming (Dev *et al*., 2022). This farming system is based on the hypothesis that trees on the streets and in forests grow and thrive without further care or fertilizer. They continue to grow independently without human intervention, utilizing the minerals and nutrients in the soil, air, water and sunlight. SPNF was the first to describe this idea (Bishnoi and Bhati, 2017). It advocates its position as an answer to India's growing farmer suicide rate and agrarian crisis (Babu, 2008). It emphasizes the use of native or desi cow excreta-derived inputs such as *Jeevamrita* and *Beejamrita*, coupled with cultural techniques like crop rotation, organic mulching (*Achhadana*), intercropping, irrigation in alternate furrows during noon time (Whapasa), etc., as a means to enhance productivity in horticultural crops (Sathish *et al*., 2022). Umendra Dutt, the Executive Director of the Kheti Virasat Mission in India, asserts that only one gram of dung from a desi cow harbours 3,000 million bacteria, in contrast to the 5-6 million bacteria found in a gram of dung from an American cow (Ojah *et al*., 2023).

As far as it is known, no research has been taken to explore the comparative interaction between five distinct cultivars of strawberries within the context of SPNF and CF systems under Punjab conditions. Consequently, the present study investigated the effectiveness of SPNF and CF systems on plant growth and yield performances by conducting field trials in the Doaba region of Punjab on five short-day strawberry cultivars to evaluate the growth and yield performances.

MATERIALS AND METHODS

Plant material and growing conditions

Five different cultivars of strawberry *viz*. Capri, Winter Star, Winter Dawn, Camarosa and Nabila were selected for the experimental study in the Teaching and Research Farm of Lovely Professional University (Phagwara) Punjab in the year 2021-22. Strawberries were planted during the first fortnight of October in the open field conditions. All five cultivars were planted at a 30 x 30 cm spacing each under SPNF and CF practices. The experiment included ten treatments and was laid in a factorial randomized block design (RBD) with three replicates. The treatments comprised farming methods (SPNF and CF) as one factor and cultivars as another factor and designed as V_1N (Capri), V_2N (Winter Star), V_3N (Winter Dawn, V_4N (Camarosa), V_5N (Nabila), V_1C (Capri), V_2C (Winter Star), V_3C (Winter Dawn, V_4C (Camarosa), and V_5C (Nabila). Each replicate contained 10 units of plants.

Under conventional farming, soil was fumigated with 50 g/m^2 of VAPAM® (metam sodium), one month prior to planting. The fertilizers were applied as per the practice package of Punjab Agricultural University, Ludhiana (Anonymus, 2021). A black polyethene mulch was placed over the beds to check weed growth, and the irrigation was applied at four days intervals during crop establishment stage using the drip irrigation method.

For SPNF conditions, a fallow plot was selected and subjected to soil solarization treatment for six weeks from June to July to kill soil-borne pathogens, pests, and weeds. All the SPNF components (*Jeevamrita, Ghan Jeevamrita, Beejamrita, Achhadana, neemastra and Brahmastra*) were prepared on-farm before the treatment application as listed in Table 1 (Palekar, 2006). At the initiation of the experiment, the aim was to foster the development of soil microfauna. To achieve this, the field received an initial application of ghan *Jeevamrita* one month before planting, and this process was reiterated during the plant's establishment phase. Before planting, the strawberry runners were treated with beejamrita to protect young roots from soil-borne diseases. After the crown establishment, the beds were covered with chopped paddy straw (*Achhadana*) to regulate weed population, soil temperature and moisture level. To maintain the whapasa, irrigation water was applied in the alternate furrows at noon at four-day intervals. About 5-6 foliar sprays of *Jeevamrita* were applied at 20-day intervals till the fruit maturity. For pest control, different cultural practices such as sanitation measures, weeding and hoeing were adopted along with the application of *Neemastra, Brahmastra* and fermented buttermilk.

Evaluation of growth parameters

To assess the impact of farming systems on growth parameters viz., specifically plant height (cm), plant spread in both the East-west (EW) and North-south (NS) directions, and the number of trifoliate leaves per plant, data were collected at two-time points: 45 and 90 days after planting (DAP). Toward the completion of the growth cycle, the leaf area of fully mature leaves was measured using a benchtop LICOR-3100 leaf area meter, and the outcome was quantified in square centimeters (cm^2). The leaf chlorophyll index was estimated when the plants approached the maximum vegetative growth using a SPAD-502 meter and units were expressed as SPAD. For measuring the stem girth, a digital Vernier caliper was used at the end of the cropping season and the data were recorded in centimetres.

Yield and yield attributing characters

Following fruiting, yield and yield attributing parameters such as average berry weight (g), number of berries/ plant, yield/plant (g) and yield efficiency (kg/cm^2) were also noted. The fruits were manually harvested twice weekly, with 8–10 harvestings throughout the cropping period. The recorded data encompassed total marketable berries, average berry weight (g), and total yield per plant (g). The yield efficiency (YE) calculation was performed based on leaf area, expressed as kg/cm^2 .

Statistical analysis

The data collected throughout the study underwent statistical analysis employing SPSS v. 21 software. The Duncan Multiple Range Test (DMRT) was then employed to identify homogeneous treatment sets, facilitating the derivation of conclusions (P<5%).

Table 1. Preparation of Subhash Palekar Natural Farming (SPNF) components

Component	Raw materials	Method of preparation
Beejamrita	1 kg Cow dung, 1 L cow urine, 50 g lime ($CaCO_3$), a handful forest soil, and 5 L water	All the ingredients were mixed thoroughly and incubated for one day before application.
Liquid Jeevamrita	10 kg Cow dung, 10 L cow urine, 2 kg gram flour, 2 kg jaggery, a handful forest soil, and 200 L water	All the ingredients were mixed thoroughly followed by continuous stirring in clockwise direction twice a day and incubated in shade for one week before application.
Ghan Jeevamrita	100 kg Cow dung, 10 L cow urine, 2 kg gram flour, 2 kg jaggery and a handful forest soil (uncontaminated soil)	All the ingredients were mixed together and spread in the shade for one week before application.
Achhadana	Paddy straw, wheat husk, or any plant residue	Paddy straws were chopped into small pieces and evenly spread over the beds under natural farming system.
Neemastra	10 kg neem leaves, 10 L cow urine, 2 kg cow dung and 200 L water	All the ingredients were boiled in an earthen pot and stored for application.
Brahmastra	3 kg neem leaves, 10 L cow urine, 2 kg papaya leaves, 2 kg custard apple leaves, and 2 kg pomegranate leaves	

Table 2. Effect of natural and conventional farming methods on plant height, plant spread and no. of trifoliate leaves of strawberry cultivars

Treatments	Plant height (cm)		Plant spread EW (cm)		Plant spread NS (cm)		No. of trifoliate leaves per plant	
	45 DAP	90 DAP	45 DAP	90 DAP	45 DAP	90 DAP	45 DAP	90 DAP
V_1N	3.77^{a}	10.77^{bc}	13.40^{ab}	21.60^{d}	12.13^{bcd}	21.78^{ef}	4.77^{bc}	14.20^{ab}
V_2N	3.43^{a}	9.47^{a}	9.23^{a}	15.50^{a}	7.97^{a}	15.98^{a}	3.87^{a}	13.20^{a}
V_3N	3.70^{a}	9.83^{ab}	10.03^{ab}	17.30^{ab}	8.90^{a}	17.78^{bc}	3.17^{a}	13.20^{a}
V_4N	3.73^{a}	9.97^{ab}	9.70^{a}	19.43^{cd}	10.83^{abcd}	19.89^{d}	3.40^{a}	13.30^{ab}
V_5N	3.13^{a}	9.30^{a}	9.90^{ab}	16.97^{ab}	9.80^{abc}	16.87^{ab}	4.07^{ab}	13.83^{ab}
V_1C	5.60^{b}	12.10^{d}	14.87^{b}	23.63^{e}	13.00^{d}	24.59^{g}	4.97^{c}	16.40^{c}
V_2C	3.93^{a}	9.87^{ab}	13.07^{ab}	19.83^{cd}	9.60^{abc}	18.67^{c}	4.80^{bc}	14.27^{ab}
V_3C	4.40^{ab}	10.87^{bc}	10.53^{ab}	18.27^{bc}	9.33^{ab}	20.45^{d}	3.77^{a}	13.21^{a}
V_4C	5.47^{b}	11.20^{cd}	13.67^{ab}	20.23^{d}	12.63^{cd}	22.64^{f}	4.80^{bc}	14.50^{b}
V_5C	4.00^{a}	10.10^{ab}	13.42^{ab}	18.50^{bc}	12.47^{cd}	20.64^{de}	3.20^{abc}	13.27^{a}

Where V_1- Capri, V_2- Winter Star, V_3- Winter Dawn, V_4-Camarosa, V_5- Nabila, N- Natural Farming method and C- Conventional Farming method; *Differences marked by distinct letters in the same column are statistically significant (P<0.05)

RESULTS AND DISCUSSION

Growth indexes

Plant height, plant spread EW, spread NS, and the number of trifoliate leaves evaluated on each cultivar under SPNF and CF systems showed significant differences among the treatments (Table 2). CF recorded better vegetative growth results for all the cultivars than SPNF. Maximum plant height (5.60 and 12.10 cm) was observed in *cv*. Capri followed by *cv*. Camarosa (5.47 and 11.20 cm) under CF (V_1C and V_4C), whereas the minimum plant height (3.13 and 9.30 cm) was observed in *cv*. Nabila under SPNF system (V_5N) at 45 and 90 DAP, respectively.

Similarly, maximum plant spread (14.87 and 23.63 cm EW; 13.00 and 24.59 cm NS) was observed in *cv*. Capri (V_1C) under CF system at 45 and 90 DAP, respectively, closely followed by *cv*. Camarosa under the same farming system (V_4C). However, SPNF system failed to impact the plant spread *vis a vis* CF system, recording a minimum plant spread in *cv*. Winter Star (V_2N) at 45 and 90 DAP, respectively. Capri also recorded a maximum number of leaves (4.97 and 16.40 at 45 and 90 DAP, respectively) under CF system (V_1C), which was significantly higher to others under both the farming systems.The Winter Dawn cultivar, under the SPNF system (V_4C), exhibited the lowest number of leaves at 45 DAP (3.17) and 90 DAP (13.20). Notably, the leaf count at 90 DAP was comparable to that of Winter Star under the same farming system, emphasizing similarities in leaf development between the two cultivars after 90 days of planting.

The mean plant height, plant spread, and number of trifoliate leaves per strawberry plant at both intervals (45 and 90 DAP) were significantly more on the side of *cv*. Capri under CF (V_1C) than the other treatments; however, this treatment behaved statistically similar to V_4C (Camarosa under CF) at both intervals. Capri, an early variety, had the privilege of utilizing the nutrients available through CF inputs better than other varieties, resulting in more precocious crops. Also, this cultivar had maximum duration from planting till advancing into the reproductive phase, allowing for an enhanced growth performance compared to other cultivars. The low performance of cultivars under the SPNF system may be because the organic inputs have slow-release characteristics, which enable sustained availability of nutrients to the plants but do not support the immediate vegetative growth of the plant. Similar to the present findings, improved performance of strawberry has been reported under conventional farming system compared to the organic farming system (Zahid *et al*., 2022; Kilic *et al*., 2021; Conti *et al*., 2014; Baruzzi *et al*., 2009). Furthermore, Vinay *et al*. (2020) observed that maize plants in inorganic farming exhibited increased height and a higher leaf count than those in organic and natural farming systems.

Chlorophyll index, leaf area and stem girth

Chlorophyll index, leaf area and stem girth showed higher levels under CF system (Table 3). Maximum chlorophyll index (56.90 SPAD) was recorded in cultivar Camarosa under CF system (V_4C). All the cultivars under CF cultivation system recorded higher chlorophyll index than SPNF. Cultivar Capri (V_1C) recorded a higher leaf area (47.76 cm^2) and stem girth (2.51 cm), which are comparable to the leaf area (45.84 cm^2) and stem girth (2.45 cm) of Camarosa (V_4C), respectively, and are significantly different from all other treatments.

The nutrients under CF system are readily available and translocated to the aerial parts of the plants (Boone *et al*., 2019) compared to SPNF practices, which take relatively more time to release the nutrients (Shaji *et al*., 2021). Moreover, nitrogen (N), the leaf chlorophyll's chief component, increased the leaf chlorophyll index under conventional farming system (Zhang *et al*.,

Table 3. Effect of natural and conventional farming methods on chlorophyll index, leaf area and stem girth of strawberry cultivars

Treatments	Chlorophyll index (SPAD)	Leaf area (cm^2)	Stem girth (cm)
V_1N	43.47^{a}	42.57^{bc}	2.21^{a}
V_2N	49.00^{bcd}	38.56^{a}	2.07^{a}
V_3N	50.73^{de}	39.45^{a}	2.07^{a}
V_4N	49.87^{cde}	39.13^{a}	2.07^{a}
V_5N	47.90^{bc}	38.55^{a}	2.05^{a}
V_1C	46.90^{b}	47.76^{e}	2.51^{b}
V_2C	52.40^{ef}	40.76^{ab}	2.10^{a}
V_3C	51.83^{e}	43.87^{cd}	2.09^{a}
V_4C	56.90^{g}	45.84^{de}	2.45^{b}
V_5C	54.57^{fg}	39.23^{a}	2.12^{a}

Where V1- Capri, V2- Winter Star, V3- Winter Dawn, V4- Camarosa, V5- Nabila, N- Natural Farming method and C- Conventional Farming method ; *Differences marked by distinct letters in the same column are statistically significant (P<0.05)

Table 4. Effect of natural and conventional farming methods on no. of fruits/plant, average berry weight, yield/plant and yield efficiency of strawberry cultivars

Treatments	No. of fruits/ Plant	Average berry weight (g)	Yield/ plant (g)	Yield efficiency (kg/cm^2)
V_1N	26.14^{e}	12.58^{a}	328.53^{b}	0.66^{a}
V_2N	19.27^{b}	11.53^{a}	221.70^{a}	0.63^{a}
V_3N	21.06^{cd}	11.90^{a}	250.57^{a}	0.73^{a}
V_4N	22.19^{d}	16.53^{b}	368.11^{b}	0.77^{a}
V_5N	20.76^{c}	12.23^{a}	253.95^{a}	0.72^{a}
V_1C	20.15^{ab}	11.97^{a}	241.98^{a}	0.61^{a}
V_2C	17.08^{a}	14.87^{ab}	254.54^{a}	0.75^{a}
V_3C	19.28^{b}	12.44^{a}	240.52^{a}	0.73^{a}
V_4C	19.30^{b}	11.53^{a}	223.02^{a}	0.68^{a}
V_5C	19.34^{a}	11.60^{a}	224.34^{a}	0.68^{a}

Where V1- Capri, V2- Winter Star, V3- Winter Dawn, V4- Camarosa, V5- Nabila, N- Natural Farming method and C- Conventional Farming method ; *Differences marked by distinct letters in the same column are statistically significant (P<0.05)

2021). In the present study, the potential N uptake may, for a while, be more than the total N that has been mineralized, lowering the amount of chlorophyll in the plants grown naturally. The cumulative mineralized N satisfied the N need at the beginning of the plant development, but it would have been challenging for the available organic N to fulfil peak demands at the end of the cropping season without applying too much organic N to the soil both before and after crop establishment. Similar effects of nitrogen on strawberry plants under conventional and vertical farming systems have also been reported (Mustafa and Rahman, 2021). Although the inputs used in natural farming are rich carriers of microbial load and compounds that support metabolic activity, disease and pest resistance, which in turn sustain plant growth and increase yield performance, they might not be enough to meet the quick nutritional demand of the crop for vigorous growth, which could result in lower leaf area and stem girth in naturally grown strawberries. Comparable results about increased leaf area and dry matter in black gram with the recommended dose of fertilizers compared to liquid organics have also been reported (Bhargavi *et al*., 2022).

Yield and yield attributing traits

Data related to yield and yield contributing characteristics, viz. average berry weight, total number of fruits per plant, and yield efficiency shown in Table 4, depict a markable variation. Cultivar Capri produced significantly more fruits (26.14) when grown naturally (V_1N) compared to Winter Star, which produced the fewest (17.08) when grown conventionally (V_2C). However, the cultivar Camarosa under SPNF (V_4N) was able to produce the largest average berry weight (16.53 g), which was at par with cultivar Winter Star (14.87 g) under CF (V_4C). On the other hand, the cultivar Camarosa grown under SPNF (V_4N) produced a greater yield per plant (368.11 g), ultimately related to a higher yield efficiency of 0.77 kg/cm^2 under the same farming system.

The assimilatory surface of the plant system affects the yield performance of any plant. Even yet, it makes sense that a consistent source in terms of plant growth, leaf count, LAI, and the number of supporting branches might raise the dry matter, and its distribution throughout different locations would be crucial for deciding the crop's total yield (Krishnamurthy and Kumar, 2012). However, SPNF did not initially have a major impact on vegetative growth; but instead, its slow-releasing effect increased the yield owing to assimilatory accumulation in the plant parts contrary to CF, which resulted in lower yields due to the exhaustion of all the nutrients for vegetative growth only. Babalad *et al*. (2021) recorded higher yields in millet under rainfed conditions with zero -budget natural farming (ZBNF) compared to conventional farming practices. Likewise, Sutar *et al*. (2019) have reported the related outcomes in cowpeas using *Jeevamrita* @ 1000 L ha^{-1} along with 7.5% *Panchagavya*. Similarly, the beneficial impacts of *Jeevamrita* were ascribed to its elevated microbial content and growth-promoting hormones. These factors likely contributed to enhanced soil biomass, fostering the availability and absorption of both introduced and inherent soil nutrients, culminating in improved crop yields (Devakumar *et al*., 2014). Also, the occurrence of beneficial microorganisms such as *Trichoderma*, *Pseudomonas fluorescens*, *Bacillus subtilis*, *Beauveria bassiana, Metarhizium spp.* etc., in *Jeevamrita,* helps suppress soil-borne pathogens and several other pathogenic microorganisms (Tutika *et al*., 2018), leading to healthy crops.

Conclusion

Although conventional farming encouraged quick vegetative growth in all the strawberry cultivars, superior yield performances were attained under SPNF, which is crucial at the commercial level. As a result, SPNF can be regarded as the ideal farming technique for strawberry cultivation because it not only fosters a healthy environment but also enriches the soil with various advantageous microorganisms while requiring little to no inexpensive inputs, ultimately promoting healthy crops. Due to the wider adaptability, vigorous growth, disease and insect resistance, and capacity to produce larger-sized fruits under any circumstances, Camarosa cultivar of strawberry exhibited the best performance under both natural and conventional farming techniques in terms of consistent growth and yield. The present study inferred that the Camarosa cultivar outperformed the other four cultivars in SPNF and CF regimes.

Conflict of interest

The authors declare that they have no conflict of interest.

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