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RESPONSE OF FRUIT QUALITY PARAMETERS AND BIOACTIVE COMPOUNDS OF STRAWBERRY (*Fragaria × ananassa* duch.) CV. WINTER DAWN TO ORGANIC COMPOST GRANULES AND BIODYNAMIC PREPARATIONS

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ABSTRACT

The present investigation was conducted during 2024–25 and 2025–26 at the Horticulture Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, to evaluate the influence of organic compost granules and biodynamic preparations on fruit quality attributes and bioactive compounds of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn. The experiment was laid out in a Split Plot Design comprising sixteen treatment combinations with three replications. Four compost granule treatments, viz., P0 (Control), P1 [50% Vermicompost + 50% Enriched Compost], P2 [50% Vermicompost + 50% NADEP Compost] and P3 [33% Vermicompost + 33% Enriched Compost + 33% NADEP Compost], were assigned to the main plots, while four biodynamic formulations, viz., FS0 (Control), FS1 (BD-500), FS2 (BD-501) and FS3 (BD-500 + BD-501), were allocated to the sub-plots. The results of compost granules and biodynamically treated treatments revealed significant variation on all the parameters studied viz., total soluble solids (TSS), titratable acidity, TSS/Acid ratio, ascorbic acid content and anthocyanin content of strawberry fruits. Among the compost granule treatments, P3 recorded the highest TSS (12.76 °Brix), TSS/Acid ratio (18.46), ascorbic acid content (54.05 mg 100 g^{-1}) and anthocyanin content (42.94 mg 100 g^{-1}), along with the lowest titratable acidity (0.70%). Similarly, among the biodynamic formulations, FS3 exhibited superior fruit quality by recording the maximum TSS (12.29 °Brix), TSS/Acid ratio (17.67), ascorbic acid content (53.83 mg 100 g^{-1}) and anthocyanin content (42.72 mg 100 g^{-1}), whereas the minimum titratable acidity (0.71%) was observed under the same treatment. The enhancement in fruit quality and bioactive compounds under integrated compost granule and biodynamic treatments may be attributed to improved nutrient availability, enhanced physiological activity, efficient carbohydrate metabolism and stimulation of secondary metabolite biosynthesis. The findings indicate that the combined application of vermicompost, enriched compost, NADEP compost and biodynamic preparations offers a sustainable strategy for improving fruit quality and nutritional value of strawberry under semi-arid conditions.

Keywords **:** Strawberry, compost granules, biodynamic preparations, fruit quality, total soluble solids, titratable acidity, ascorbic acid, anthocyanin content, organic nutrient management, Winter Dawn.

Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most economically important berry crops cultivated worldwide owing to its attractive appearance, unique flavour, pleasant aroma and exceptional nutritional value. The fruit is highly appreciated by consumers because of its richness in vitamins, minerals, dietary fibre and numerous bioactive compounds, particularly anthocyanins, phenolic compounds and ascorbic acid. These compounds contribute substantially to the antioxidant

capacity of strawberry fruits and provide protection against several chronic diseases and oxidative stress-related disorders (Giampieri *et al*., 2012). In recent decades, strawberry cultivation has expanded considerably in India due to increasing consumer demand, diversification of horticultural production systems and the crop's potential for generating higher economic returns. Among the commercially cultivated cultivars, 'Winter Dawn' has gained prominence because of its early bearing habit, attractive fruit quality and adaptability to diverse agro-climatic conditions. Fruit quality is a multifaceted characteristic determined by physical, chemical and nutritional attributes that collectively influence consumer acceptance and market value. Among the various quality parameters, total soluble solids (TSS), titratable acidity and TSS/ Acid ratio are considered major determinants of fruit flavour and palatability. The balance between sugars and organic acids largely governs sweetness, taste and overall eating quality of strawberry fruits. During fruit ripening, accumulation of soluble sugars leads to increased TSS, whereas organic acids decline progressively, resulting in an improved TSS/Acid ratio and enhanced fruit flavour (Ornelas-Paz *et al*., 2013). Therefore, management practices capable of improving these quality attributes are essential for enhancing marketability and consumer preference.

Apart from sensory quality, the nutritional and functional properties of strawberry fruits have received considerable attention in recent years. Ascorbic acid (vitamin C) is one of the most important natural antioxidants present in strawberry fruits and plays a vital role in human nutrition by protecting cellular components against oxidative damage and supporting immune function (Giampieri *et al*., 2012). Similarly, anthocyanins are the principal pigments responsible for the characteristic red colour of strawberry fruits and possess strong antioxidant, anti-inflammatory and nutraceutical properties (Crecente-Campo *et al*., 2012). Considerable variability in ascorbic acid and anthocyanin content among strawberry cultivars and production environments has been reported by Lal *et al*. (2013) and Gündüz and Özdemir (2014), highlighting the importance of appropriate crop management practices for improving fruit nutritional quality. Nutrient management plays a pivotal role in determining fruit quality and biochemical composition of strawberry. Although the extensive use of chemical fertilizers has substantially increased agricultural productivity, their continuous and indiscriminate application has raised concerns regarding soil degradation, nutrient imbalance and environmental sustainability. Consequently, organic nutrient management approaches have gained increasing importance in modern horticulture. Organic amendments such as vermicompost, enriched compost and NADEP compost improve soil physical, chemical and biological properties while ensuring a gradual and balanced supply of nutrients throughout the crop growth period. These organic inputs stimulate microbial activity, improve nutrient-use efficiency and favour the synthesis and accumulation of sugars, vitamins and antioxidant compounds in fruits (Kilic *et al*., 2021). Furthermore, organically managed strawberry plants have been reported to produce fruits with enhanced antioxidant activity and improved nutritional quality compared to conventional production systems (Kristl *et al*., 2013).

In addition to organic nutrient sources, biodynamic agriculture has emerged as an important component of sustainable crop production systems. Biodynamic preparations such as BD-500 (horn manure) and BD-501 (horn silica) are believed to stimulate biological processes within the soil–plant system and enhance the efficiency of natural ecological interactions. BD-500 primarily promotes root development, rhizospheric microbial activity and nutrient mobilization, whereas BD-501 improves photosynthetic efficiency, light utilization and assimilate production within plant tissues. The combined action of these preparations may positively influence carbohydrate metabolism and biosynthesis of antioxidant compounds, ultimately improving fruit quality and nutritional composition. Although the beneficial effects of organic nutrient sources on strawberry fruit quality have been documented, information regarding the combined application of compost granules and biodynamic preparations on fruit quality attributes and bioactive compounds of strawberry remains limited, particularly under the semi-arid agro-climatic conditions of southern Rajasthan. Understanding the synergistic influence of these sustainable nutrient management approaches is essential for developing environmentally sound production practices capable of improving fruit quality and nutritional value. Therefore, the present investigation was undertaken to evaluate the response of fruit quality parameters and bioactive compounds of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn to organic compost granules and biodynamic preparations under semi-arid conditions.

Material and Methods

The present investigation was conducted during 2024–25 and 2025–26 at Horticulture Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan. The

experiment was laid out in a Split Plot Design with three replications. Four compost granule treatments viz., P0 (Control), P1 [50% Vermicompost + 50% Enriched Compost], P2 [50% Vermicompost + 50% NADEP Compost] and P3 [33% Vermicompost + 33% Enriched Compost + 33% NADEP Compost] were assigned to the main plots, while four biodynamic formulations viz., FS0 (Control), FS1 (BD-500), FS2 (BD-501) and FS3 (BD-500 + BD-501) were allocated to the sub-plots, resulting in sixteen treatment combinations. Healthy runners of strawberry cv. Winter Dawn were procured from a reputed nursery and transplanted on raised beds following recommended cultural practices. Compost granules were applied before transplanting as per treatment specifications, whereas BD-500 was applied as a soil drench before planting and BD-501 was sprayed foliarly at 15 days after transplanting and at the flowering stage. Fully ripe and healthy fruits were harvested from five randomly selected plants in each treatment for quality evaluation. The observations recorded included total soluble solids (TSS), titratable acidity, TSS/Acid ratio, ascorbic acid content and anthocyanin content. The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Split Plot Design following the procedure outlined by Panse and Sukhatme (1985). The significance of treatment differences was tested using the F-test at the 5 per cent level of significance, and critical difference (C.D.) values were calculated wherever treatment effects were found significant.

Quality Analysis

Total soluble solids (TSS) of strawberry fruits were determined using a hand refractometer and expressed as °Brix following the procedure described by Ranganna (1986). Titratable acidity was estimated by titrating the fruit extract against 0.1 N sodium hydroxide using phenolphthalein as an indicator and expressed as percentage citric acid equivalent according to the method of A.O.A.C. (1980). The TSS/Acid ratio was calculated by dividing the corresponding TSS value by titratable acidity. Ascorbic acid content was determined by the visual titration method using 2,6-dichlorophenol indophenol dye and expressed as mg 100 g^{-1} fresh pulp (Ranganna, 1986). Anthocyanin content was estimated spectrophotometrically after extraction with acidified methanol according to the method described by Harborne (1973) and Ranganna (1986), and the results were expressed as mg 100 g^{-1} fresh fruit weight.

Results and Discussion

Effect of Compost Granules on Fruit Quality Parameters and Bioactive Compounds

The fruit quality attributes and bioactive compounds of strawberry cv. Winter Dawn were significantly influenced by the application of compost granules (Table 1 and Figure 1). Among the different compost granule treatments, P3 [33% Vermicompost + 33% Enriched Compost + 33% NADEP Compost] recorded the highest total soluble solids (12.76 °Brix), TSS/Acid ratio (18.46), ascorbic acid content (54.05 mg 100 g^{-1}) and anthocyanin content (42.94 mg 100 g^{-1}), whereas the lowest titratable acidity (0.70%) was observed under the same treatment. In contrast, the control treatment (P0) recorded the lowest TSS (8.07 °Brix), TSS/Acid ratio (9.37), ascorbic acid content (49.04 mg 100 g^{-1}) and anthocyanin content (33.68 mg 100 g^{-1}), along with the highest titratable acidity (0.87%). The enhancement in TSS under P3 may be attributed to the balanced and continuous supply of nutrients from vermicompost, enriched compost and NADEP compost, which improved photosynthetic efficiency and carbohydrate synthesis. Potassium supplied through organic sources plays a crucial role in translocation and accumulation of sugars in fruits, resulting in increased soluble solids. Similar improvements in TSS under organic nutrient management were reported by Kilic *et al.* (2021) and Kristl *et al*. (2013). The reduction in titratable acidity observed under integrated compost application may be associated with enhanced metabolic conversion of organic acids into sugars during fruit maturation. Consequently, the higher TSS and lower acidity contributed to a significant increase in the TSS/Acid ratio, which is considered an important indicator of flavour quality and consumer acceptability (Ornelas-Paz *et al*., 2013).

The increased ascorbic acid content under P3 could be attributed to improved nutrient availability and enhanced synthesis of carbohydrate precursors involved in vitamin C biosynthesis. Organic nutrient sources are known to stimulate enzymatic activities and physiological processes that favour the accumulation of antioxidant compounds in fruits. Similar findings were reported by Crecente-Campo *et al*. (2012) and Lal *et al*. (2013), who observed higher vitamin C content in organically managed strawberry fruits. Likewise, the higher anthocyanin content recorded under P3 may be due to enhanced synthesis of phenolic compounds and improved availability of micronutrients involved in pigment biosynthesis. Increased anthocyanin accumulation under organic production systems has also been documented by

Crecente-Campo *et al*. (2012) and Gündüz and Özdemir (2014). The results clearly indicate that integrated application of compost granules significantly improved the sensory, nutritional and functional quality of strawberry fruits.

Effect of Biodynamic Formulations on Fruit Quality Parameters and Bioactive Compounds

Biodynamic formulations exerted a significant influence on fruit quality parameters and bioactive compounds of strawberry (Table 2 and Figure 2). Among the treatments, FS3 (BD-500 + BD-501) recorded the highest TSS (12.29 °Brix), TSS/Acid ratio (17.67), ascorbic acid content (53.83 mg 100 g^{-1}) and anthocyanin content (42.72 mg 100 g^{-1}), while the lowest titratable acidity (0.71%) was observed under the same treatment. The minimum values of TSS (9.83 °Brix), TSS ratio (12.68), ascorbic acid content (50.32 mg 100 g^{-1}) and anthocyanin content (36.27 mg 100 g^{-1}), along with the highest acidity (0.79%), were recorded under the control treatment (FS0). The favourable effect of FS3 may be attributed to the complementary action of BD-500 and BD-501 in improving nutrient uptake, photosynthetic activity and metabolic efficiency of plants. BD-500 enhances soil microbial activity and root development, thereby facilitating nutrient absorption, whereas BD-501 improves light utilization and photosynthetic performance, resulting in greater production and translocation of photosynthates towards developing fruits. Enhanced carbohydrate accumulation consequently increased TSS values and improved fruit sweetness. Similar observations regarding the positive influence of biodynamic preparations on fruit quality have been reported by Reeve *et al*. (2005) and Carpenter-Boggs *et al*. (2000). The lower titratable acidity and higher TSS/Acid ratio observed under FS3 may be due to accelerated utilization of organic acids during ripening and improved sugar accumulation within fruit tissues. Furthermore, increased photosynthetic activity and efficient assimilate partitioning may have favoured biosynthesis of ascorbic acid, resulting in significantly higher vitamin C content. The enhancement in anthocyanin concentration may be associated with stimulation of secondary metabolic pathways responsible for pigment synthesis and antioxidant accumulation. Similar trends of improved antioxidant content and enhanced fruit quality under biodynamic and organic management systems have been reported by Reeve *et al*. (2005), Gündüz and Özdemir (2014) and Lal *et al*. (2013).

Overall, the results of the present investigation demonstrate that both compost granules and biodynamic formulations significantly improved fruit quality and bioactive compounds of strawberry cv. Winter Dawn. The integrated compost granule treatment P3 and the combined biodynamic formulation FS3 proved most effective in enhancing TSS, TSS/Acid ratio, ascorbic acid and anthocyanin content while reducing titratable acidity, thereby producing fruits of superior nutritional and market quality.

Table 1: Effect of compost granules on fruit quality parameters and bioactive compounds of strawberry c.v. Winter Dawn.

Treatment	TSS (˚brix)	Titrable acidity (%)	TSS/Acid	Ascorbic acid (mg 100 g^{-1})	Anthocyanin content (mg 100 g^{-1})
P0	8.07	0.87	9.37	49.04	33.68
P1	11.91	0.72	16.63	52.95	41.05
P2	12.16	0.71	17.11	52.73	40.19
P3	12.76	0.70	18.46	54.05	42.94
SEm±	**0.01**	**0.002**	**0.02**	**0.08**	**0.05**
C.D. @ 5%	**0.04**	**0.006**	**0.06**	**0.25**	**0.16**

Table 2: Effect of biodynamic formulations on fruit quality parameters and bioactive compounds of strawberry c.v. Winter Dawn.

Treatment	TSS (˚brix)	Titrable acidity (%)	TSS/Acid	Ascorbic acid (mg 100 g^{-1})	Anthocyanin content (mg 100 g^{-1})
FS0	9.83	0.79	12.68	50.32	36.27
FS1	11.13	0.76	15.02	52.03	38.05
FS2	11.67	0.74	16.20	52.59	40.81
FS3	12.29	0.71	17.67	53.83	42.72
SEm±	**0.01**	**0.002**	**0.02**	**0.06**	**0.04**
C.D. @ 5%	**0.03**	**0.005**	**0.05**	**0.17**	**0.11**

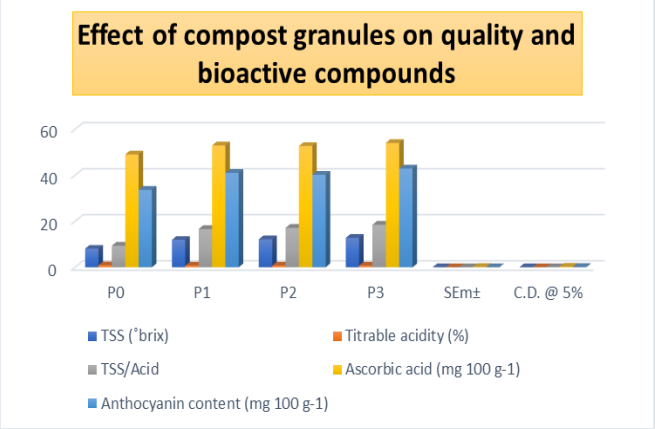

Fig. 1: Effect of compost granules on quality and bioactive compounds of strawberry c.v. Winter Dawn.

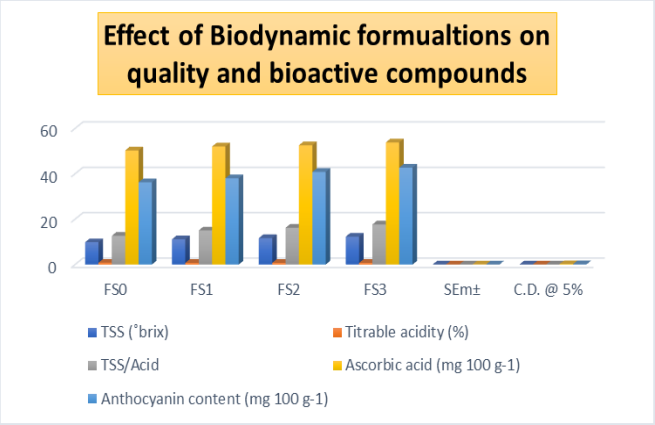

Fig. 2: Effect of biodynamic formulations on quality and bioactive compounds of strawberry c.v. Winter Dawn.

Conclusion

The findings of the present investigation clearly demonstrated that the application of organic compost granules and biodynamic formulations significantly improved the fruit quality attributes and bioactive compounds of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn under semi-arid conditions of southern Rajasthan. Among the compost granule treatments, P3 [33% Vermicompost + 33% Enriched Compost + 33% NADEP Compost] proved to be the most effective, recording the highest total soluble solids (12.76 °Brix), TSS ratio/Acid (18.46), ascorbic acid content (54.05 mg 100 g^{-1}) and anthocyanin content (42.94 mg 100 g^{-1}), along with the lowest titratable acidity (0.70%). Similarly, among the biodynamic formulations, FS3 (BD-500 + BD-501) produced superior quality fruits with maximum TSS (12.29 °Brix), TSS/Acid ratio (17.67), ascorbic acid content (53.83 mg 100 g^{-1}) and anthocyanin content (42.72 mg 100 g^{-1}), while recording minimum titratable acidity (0.71%). The improvement in fruit quality under these treatments may be attributed to enhanced nutrient availability, improved photosynthetic efficiency, better carbohydrate accumulation and increased biosynthesis of antioxidant compounds. Therefore, the integrated application of compost granules comprising vermicompost, enriched compost and NADEP compost in combination with biodynamic preparations (BD-500 and BD-501) can be recommended as a sustainable nutrient management strategy for producing high-quality strawberry fruits with improved nutritional and functional properties.

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