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Off-season Production of Bell Pepper (*Capsicum anuum*, L.) as Influenced by Soil Enhancers and Mulching Materials

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ABSTRACT

Bell pepper (Capsicum annuum) is a widely cultivated crop known for its vibrant colors, sweet flavor, and nutritional benefits. Belonging to the Solanaceae family, it is a versatile vegetable commonly used in culinary dishes around the world. The study evaluated the off-season production of bell pepper, a total of 1,152 seedlings were sown, transplanted, and distributed across 48 plots measuring 4.4 square meters each. Each plot accommodated 24 seedlings, with meticulous care and observation maintained throughout the study. The research employed a 2x4 factorial design to assess the influence of soil enhancers and mulching materials on bell pepper cultivation. The treatments consisted of two factors: soil enhancers (Factor A) and mulching materials (Factor B). Factor A included four treatments: A1 (control), A2 (carabao manure), A3 (goat manure), and A4 (chicken manure). Factor B comprised four mulching materials: B1 (control), B2 (rice hull), B3 (rice straw), and B4 (plastic mulching). Data analysis was conducted using the analysis of variance in a randomized complete block design (RCBD), with mean comparisons facilitated through Duncan's Multiple Range Test (DMRT). The study's findings highlighted the substantial impact of soil enhancers, particularly chicken manure, on the vegetative growth phase of bell pepper. Furthermore, the combined application of soil enhancers and mulching materials, as well as individual applications, significantly affected the development of fruiting branches, with chicken manure notably enhancing the diameter of bell pepper fruits. The research suggests that utilizing soil enhancers, especially chicken manure, constitutes a promising approach to improve bell pepper vegetative growth during off-season production.

RESUMO

O pimentão (Capsicum annuum) é uma cultura amplamente cultivada, conhecida por suas cores vibrantes, sabor doce e benefícios nutricionais. Pertencente à família Solanaceae, é um vegetal versátil comumente usado em pratos culinários ao redor do mundo. O estudo avaliou a produção fora de temporada de pimentão, um total de 1.152 mudas foram semeadas, transplantadas e distribuídas em 48 parcelas medindo 4,4 metros quadrados cada. Cada parcela acomodou 24 mudas, com cuidados meticulosos e observação mantida durante todo o estudo. A pesquisa empregou um delineamento fatorial 2x4 para avaliar a influência de melhoradores de solo e materiais de cobertura morta no cultivo de pimentão. Os tratamentos consistiram em dois fatores: melhoradores de solo (Fator A) e materiais de cobertura morta (Fator B). O Fator A incluiu quatro tratamentos: A1 (controle), A2 (esterco de carabao), A3 (esterco de cabra) e A4 (esterco de galinha). O fator B compreendeu quatro materiais de cobertura morta: B1 (controle), B2 (casca de arroz), B3 (palha de arroz) e B4 (cobertura morta de plástico). A análise de dados foi conduzida usando a análise de variância em um delineamento de blocos completos casualizados (DCC), com comparações médias facilitadas pelo teste de múltiplos intervalos de Duncan (DMRT). As descobertas do estudo destacaram o impacto substancial dos melhoradores de solo, particularmente esterco de galinha, na fase de crescimento vegetativo do pimentão. Além disso, a aplicação combinada de melhoradores de solo e materiais de cobertura morta, bem como aplicações individuais, afetou significativamente o desenvolvimento de ramos frutíferos, com o esterco de galinha aumentando notavelmente o diâmetro dos frutos do pimentão. A pesquisa sugere que a utilização de melhoradores de solo, especialmente esterco de galinha, constitui uma abordagem promissora para melhorar o crescimento vegetativo do pimentão durante a produção fora de temporada.

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Introduction

Bell pepper (Capsicum annuum L.), also known as 'sweet pepper', is a versatile vegetable available in various colors, including red, green, yellow, brown, and orange. It is also referred to by other names such as capsicum, pepper, chili, chile, chilli, aji, or paprika. Bell peppers are rich in essential nutrients, particularly vitamins A and C, as well as potassium (Mariano & Jimenez, 2021).

In the 2020 pepper season, the pepper planting area in Southeast Asia expanded to 814,000 hectares, marking a 1.9% increase from the previous year. The total output rose to 19.6 million tons, a 3.1% increase compared to the prior year. Regarding trade, 49,800 tons were imported, while the export volume reached 112,400 tons (FAO, 2021).

In the Philippines, bell pepper production has shown a positive trend from 2019 to 2021. Production levels ranged from 13.95 thousand metric tons to 15.96 thousand metric tons, with an average annual increase of 7.0% over the three-year period. The average annual bell pepper production or consumption was 14.20 thousand metric tons. According to records (PSA, 2021), production increased by 0.92 thousand metric tons, from 13.26 thousand metric tons in 2019 to 14.18 thousand metric tons in 2020, and further rose by 0.98 thousand metric tons to reach 15.16 thousand metric tons in 2021. On a per capita basis, the average net food disposable for bell pepper was only 0.13 kilograms per year, with an average growth rate of 4.7%.

In the Bicol region, including Masbate Province, the value of bell pepper production showed fluctuations over three reference years, amounting to 53 million PhP, 50 million PhP, and 47 million PhP, respectively. The growth rate declined by 4.3% from 2017 to 2018 and further decreased by 6.5% from 2018 to 2019 (PSA, 2021). With the growing population and increased awareness of the importance of nutrition in daily diets, the significance of vegetables, including bell peppers, has become more pronounced. Vegetables provide essential nutrients such as vitamins and minerals, which has led to an increased demand for their production (Maitra, 2020). However, seasonal vegetable production under open field conditions often falls short of meeting the rising population's needs. This shortfall has led to the adoption of off-season cultivation of vegetables, a practice that involves growing crops outside the normal cropping calendar. Off-season cultivation is typically adopted when supply is low and prices are high, ensuring a year-round availability of vegetables (Maitra, 2020).

While the use of inorganic fertilizers can increase crop yields, it can also deplete soil fertility in the long run. Today, farmers often prioritize inorganic fertilizers for commercial production, sometimes overlooking the impact on consumer health and soil sustainability. Organic fertilizers, acting as soil enhancers and conditioners, play a significant role in vegetable production by reducing input costs (Greer & Diver, 2000). Organic manure contains essential nutrients found in inorganic fertilizers (Murphy, 2006), offering a significant cost advantage as a soil enhancer. Farmers are particularly conscious of production costs, as profits are determined by input expenses.

Managing weed growth, which competes for nutrient absorption and disrupts the presence of essential microorganisms, poses a challenge in bell pepper production. One economical solution to address this issue is the application of mulching materials. Mulching materials help suppress weeds, enhance soil organic matter and nutrient retention, and maintain an optimal soil temperature for microbial activities in the root zone (Biswas et al., 2021).

This study was conducted to evaluate the effects of different soil enhancers and mulching materials on the off-season production of bell pepper (Capsicum annuum L.). Specifically, the study aimed to assess the effects of these treatments on the following growth parameters: number of days to flower, height of plant at flowering, number of days to first harvest, length of fruits, number of fruiting branches per plant at last harvesting, marketable yield per plot and per hectare in kilograms, and non-marketable yield per plot and per hectare in kilograms.

Materials and methods

Materials

The study was carefully planned and executed using a variety of materials for accuracy and efficiency. The primary planting materials were California Wonder bell pepper seeds. To enrich the soil, organic fertilizers such as goat manure, carabao manure, and chicken manure were applied. Data gathering and recording were conducted with a steel tape and a record book, ensuring precise measurements and documentation.

The layout of the planting area was organized using nylon and a shovel. Seeds were sown in a seedling tray covered with polyethylene plastic to maintain optimal conditions. A sprinkler was used for regular watering. Documentation was essential, with a camera capturing visual records of plant growth. This comprehensive approach ensured the reliability of the study's findings.

Research design

The study utilized a 2x4 factorial experiment, arranged in a Randomized Complete Block Design (RCBD) with three replications, to thoroughly investigate the effects of different treatments. Factor A in the experiment examined the influence of various soil enhancers: A1 served as the control with no enhancer, while A2, A3, and A4 used carabao manure, goat manure, and chicken manure, respectively. Factor B explored the impact of different types of mulch: B1 was the control with no mulch, and B2, B3, and B4 used rice hulls, rice straw, and plastic, respectively.

The experimental area covered a total of 355.95 m^2, divided into three equal blocks of 118.65 m^2 each. Within each block, there were 16 plots, each measuring 2.2 m x 2 m (4.4 m^2). The plots were spaced 1 meter apart between blocks and 0.5 meters apart within blocks. Each plot was prepared with four shallow furrows, spaced 60 cm apart, and each furrow had a 10 cm margin from the plot's edges. In each furrow, six seedlings were planted at 35 cm intervals, with a 10 cm margin from both ends, totaling 24 seedlings per plot. For data collection, 10 seedlings from each plot were selected to assess growth and yield parameters. This meticulous design ensured comprehensive evaluation of the different treatments and their effects on plant performance.

Cultural management practices

A nursery measuring 2.0 meters by 5.0 meters was strategically placed near experimental fields to cultivate sweet pepper (Capsicum annuum L.) seedlings. Seeds were individually sown in black plastic trays filled with a mixture of garden soil and organic compost. After sowing, seedling trays were misted to promote germination and subsequently watered regularly to foster growth.

Twenty-five (25) days post-germination, seedlings underwent a hardening process, gradually exposed to sunlight to enhance resilience before final transplanting. Meanwhile, the experimental field underwent thorough soil preparation through plowing and harrowing, creating raised beds measuring 30 cm high, 2 meters wide, and 2.2 meters long.

The field layout adhered to strict experimental design principles to ensure uniformity and facilitate robust agronomic evaluations. After 30 days, the seedlings were ready for transplanting.

Preparation and installation of mulching materials

The different mulching materials prescribed in Factor B were as follows: B1 – Control (No mulch), B2 – Rice hull, B3 – Rice straw, and B4 – Plastic. Partially decomposed rice hulls and rice straw, sourced from the institution's Rice Production project, were collected. These materials were spread on top of the experimental plots designated for Factors B2 and B3 after incorporating animal manure as a soil enhancer. The rice straw and rice hull mulch were applied to a thickness of about 8 cm over the experimental plots. In contrast, plastic mulch for Factor B4 was spread and securely fixed over its designated plots. Following this application, holes were prepared at appropriate intervals for planting sweet pepper.

Transplanting and water management

Thirty days after sowing (DAS), the seedlings of the California Wonder variety of bell pepper were transplanted into the experimental plots, adhering to a planting distance of 60 cm between rows and 35 cm between hills. Each plot, covering an area of 4.4 m^2, accommodated a total of 24 seedlings. After transplanting, the seedlings were immediately watered using a sprinkler to prevent wilting. Subsequent watering occurred daily for five (5) days to maintain soil moisture critical for the growth and development of the newly transplanted seedlings. Following this initial phase, flooded irrigation was implemented at 7-day intervals throughout the study period.

Nutrient management

Various types of properly decomposed animal manure specifically carabao, goat, and chicken were collected and utilized in this study. Each type of animal manure, totaling 10 kilograms per 4.4 m^2 plot, was applied according to Factor A – Soil enhancers, with the exception of A1 (Control - No enhancer). Thus, A2 received 10 kg of carabao manure, A3 received 10 kg of goat manure, and A4 received 10 kg of chicken manure. The animal manure, recognized for its soil enhancement properties (Murphy, 2006), was thoroughly incorporated into the experimental plots before the application of various mulching materials such as rice hulls, rice straw, and plastic mulch. This approach aimed to optimize soil fertility and prepare a conducive environment for the subsequent growth of sweet pepper seedlings.

Data gathering

The following are the data which was collected throughout the duration of the study. A total of 10 inner plants as representative samples per treatment as source of data that was gathered.

Growth performance

Days to flower. This was recorded when 50% of the experimental plants in the plot produced flowers, that is when plants showed the formation of flower buds.

Height of plant at flowering (cm). This was taken by measuring the height of 10 sample plants randomly selected from the harvest area using a meter stick. Measurement of the height was done from the soil base up to the tip of the plant when all of the plants in the experimental plots produced a flower.

Days to first harvest. This was determined by counting the number of days from the transplanting of seedlings up to the first day of harvest.

Length of fruits (cm). This was obtained by measuring 30 marketable fruits randomly selected per plot using a digital caliper. The size of harvested fruits from 10 experimental plants per plot in every treatment was measured (Borres et al., 2022). The fruit size was measured in terms of length and diameter.

Ten (10) sample fruits were taken each from the first, second, and third priming. The average length of the 30 fruits harvested from the three consecutive priming was recorded in these parameters.

Diameter of fruits (cm). The diameter was measured in the middle part of the fruit and expressed in centimeters (cm) (Borres et al., 2022). This measurement was taken from 30 marketable fruits to collect data on the fruit's length.

Number of fruiting branches per plant at last harvesting. This was taken from the 10 sample plants randomly selected from the harvest area. The branches are those shoots that came out from the lateral sides of the main stem. The branches of 10 sample plants were counted then the total was divided by 10.

Yield parameters

Marketable yield per plot. This was taken by weighing all the marketable fruits harvested from 10 sample plants per plot from the priming or harvesting of fruits and expressed in kg.

Marketable fruit yield per hectare. This was determined by recording all harvested marketable fruits per plot, as calculated using the formula from Tandzi et al. (2019) and expressed in kg ha^{-1}.

$$Fruit\ yield\ \left(\frac{kg}{ha}\right) = weight\ of\ fruit\ yield\ per\ plot\ /\ 4.4\text{m}^2\ x\ 10{,}000m^2$$

Non-marketable fruit yield per plot. This was determined by weighing all fruits harvested that were classified as non-marketable due to deformities, insect infestations, or diseases observed during priming or harvesting.

Non-marketable fruit yield per hectare. The non-marketable fruit yield per hectare was calculated by weighing all the non-marketable fruits harvested within the 4.4 m^2 plot, using the formula specified by Tandzi et al. (2019) and expressed in kg ha^{-1}.

$$Non - Marketable\ Fruit\ yield\ \left(\frac{kg}{ha}\right) = weight\ of\ fruit\ yield\ per\ plot\ /\ 4.4\text{m}^2\ x\ 10{,}000m^2$$

Results and discussion

Days to flowering

The result of study indicated that the average number of days to flowering in bell pepper plants treated with various soil enhancers ranged from 18 to 21 days. Notably, the plots with the longest time to flowering were those with no soil enhancer and those treated with goat manure, both averaging 21 days. These were followed by plots treated with carabao manure, which had a mean flowering time of 20 days. In contrast, the plots treated with chicken manure exhibited the shortest time to flowering, averaging 18 days.

This suggests that chicken manure significantly accelerates the onset of flowering in bell pepper compared to other soil enhancers. The rapid flowering observed in the chicken manure-treated plots may be attributed to its high phosphorus content, approximately 26.5 pounds per ton (Murphy, 2006). Phosphorus is known to play a crucial role in plant development, promoting stronger bud and flower formation (Rahangdale, 2018). On a broader scale, phosphorus enhances seed germination, strengthens roots, stalks, and stems, supports flower and seed development, and ultimately improves crop yield and quality (Malhotra, 2018). Table 1 illustrates the average number of days to flowering in bell pepper, influenced by various soil enhancers and mulching materials.

In terms of mulching materials, the average number of days to flowering ranged from 19 to 21 days, with minimal differences among treatments. The control plots, which did not use any mulch, exhibited the earliest flowering, likely due to their response to water stress under high temperatures during the vegetative stage (Alhasnawi et al., 2020). Plots treated with rice straw, rice hull, and plastic mulch followed, showing little variance in flowering times. This indicates that mulching materials had a negligible direct effect on the flowering timing of bell peppers.

Statistical analysis confirmed significant differences among the soil enhancer treatments, underscoring that chicken manure is particularly effective in reducing the days to flowering for bell peppers. However, the interaction between soil enhancers and mulching materials did not significantly impact the flowering timing, suggesting that while soil enhancers have a marked effect, mulching materials do not interact significantly with this factor.

Table 1.

Average number of days to flower of bell pepper as influenced by soil enhancers and mulching materials

Soil Enhancers	Mulching Materials				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	19.00	21.00	23.00	22.00	**21.00**[b]
Carabao manure	20.00	21.00	23.00	19.00	**20.00**[b]
Goat manure	19.00	20.00	22.00	21.00	**21.00**[b]
Chicken manure	19.00	18.00	18.00	20.00	**18.00**[a]
Means	**19.00**	**20.00**	**21.00**	**21.00**	
CV (%)					**10.03**

Level of significance: means with the same letter are not significantly different

Height at flowering

The study revealed that the height of bell pepper plants at flowering varied among treatments with soil enhancers, ranging from 10.09 cm to 11.57 cm. The tallest plants were found in plots treated with chicken manure, followed by untreated plots, with the mean heights being 10.25 cm, 10.10 cm, and 10.09 cm for the chicken manure, untreated, goat manure, and carabao manure treatments, respectively. Table 2 provides the average height at flowering for bell pepper, as influenced by different soil enhancers and mulching materials. These results indicate that the application of soil enhancers did not significantly affect the height of bell pepper plants at flowering.

Conversely, significant differences were observed in the height of plants among the mulching materials. The mean heights ranged from 9.82 cm to 11.75 cm, with the tallest plants being in the untreated plots (11.75 cm). This was followed by plots treated with rice straw (10.59 cm), rice hull (9.85 cm), and plastic mulch, which had the shortest plants. This suggests that mulching materials had a more pronounced effect on plant height at flowering compared to soil enhancers. The results indicate that mulching materials significantly influenced plant height at flowering. However, the interaction between soil enhancers and mulching materials did not directly impact plant height.

Statistical analysis revealed no significant differences in plant height among the soil enhancer treatments, but there were significant variations among the mulching treatments. The untreated plots showed notable differences compared to those treated with rice straw, though the differences were not drastic. This finding aligns with the study by Verma et al. (2016), which also found that untreated plots and those with specific combinations of soil enhancers exhibited similar growth patterns.

The impact of rice straw on plant height may be attributed to its ability to enhance soil fertility and microbial diversity, as noted by Cao et al. (2021). However, the plant height results from this study are not directly comparable to those of Borres et al. (2022), which ranged from 51.50 cm to 62.35 cm and also used rice straw as mulch under different photoperiod conditions. Rice straw mulching improves soil organic carbon content and supports a healthy microbial community, contributing to better plant growth and height compared to other mulching materials.

Table 2.

Average height at the flowering of bell pepper as influenced by soil enhancers and mulching materials(cm).

Soil Enhancers	Mulching Materials				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	11.70	9.33	10.27	9.69	**10.25**
Carabao manure	10.79	10.10	9.72	9.77	**10.09**
Goat manure	11.75	9.42	10.00	9.22	**10.10**
Chicken manure	12.76	10.56	12.38	10.59	**11.57**
Means	**11.75*a***	**9.85*b***	**10.59*ab***	**9.82*b***	
CV (%)					**14.60**

Level of significance: means with the same letter are not significantly different

Number of days to first harvest

Application of soil enhancers brought an average mean ranging from 75 days to 78 days. The data showed that the shortest number of days to first harvest was done in untreated plots with 75 days followed by plots treated with chicken manure with 77 days then for plots treated with carabao and goat manure with 78 days. As to the application of mulching materials, the longest number of days was recorded in plots treated with rice hull with a mean of 79, followed by untreated plots and plots treated with plastic mulching with the same mean of 77 days, and the shortest number of days was recorded in plots treated with rice straw with a mean of 76 days. This showed that the result of the study for the days to first harvest did not follow the exact trends of the days to first flowering because it was further observed that during the conduct of the study untreated plots showed early maturity indices and it was observed further that the reason was probably environmental factors occurred because the study suffered intense rainfall during vegetative stage and drought at its fruit development stage. This occurence in yield is attributed to adverse environmental conditions, including continuous rainfall during vegetative growth, drought during fruit development, and the presence of bacterial wilt and root rot disease, as outlined by Alhasnawi et al. (2020). Table 3 presents the average number of days to the first harvest of bell pepper as influenced by soil enhancers and mulching materials.

Table 3.

Average number of days to the first harvest of bell pepper as influenced by soil enhancers and mulching materials.

Soil Enhancers	**Mulching Materials**				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	74.00	77.00	75.00	75.00	**75.00**
Carabao manure	80.00	80.00	74.00	77.00	**78.00**
Goat manure	79.00	78.00	79.00	77.00	**78.00**
Chicken manure	75.00	79.00	75.00	78.00	**77.00**
Means	**77.00**	**79.00**	**76.00**	**77.00**	
CV (%)					**4.03**

Analysis of the results indicated that soil enhancers and mulching materials did not have a significant influence on the number of days to the first harvest. The treatment means were nearly identical, suggesting that neither the type of soil enhancer nor the mulching material had a direct impact on the time to the first harvest of bell peppers. This finding implies that the use of soil enhancers and the application of different mulching materials did not significantly alter the time to first harvest.

Length of fruits

The study results on fruit length indicated that the application of soil enhancers resulted in average fruit lengths ranging from 4.03 cm to 4.34 cm. The longest fruits were observed in plots treated with chicken manure, which had a mean length of 4.34 cm. This was followed by plots treated with carabao manure, with a mean length of 4.26 cm, and plots treated with goat manure, with a mean length of 4.11 cm. The untreated plots had the shortest mean fruit length at 4.03 cm.

The results for fruit length in plots treated with chicken manure are consistent with the findings of Borres et al. (2023), which showed that chicken dung resulted in longer fruits compared to other types of animal manure in chili peppers. Despite these observations, statistical analysis revealed that the application of soil enhancers did not significantly affect the length of bell pepper fruits.

In terms of mulching materials, plots treated with rice straw produced the longest fruits, with a mean length of 4.44 cm. This was followed by plots treated with plastic mulch, which had a mean length of 4.30 cm, and plots treated with rice hull, which had a mean length of 4.10 cm. The untreated plots had the shortest mean fruit length at 3.92 cm. However, the results of this study on fruit length are not comparable to those of Borres et al. (2022), which reported an average fruit length of 6.28 cm to 6.72 cm using rice straw as mulch in a different soil type. These findings suggest that the use of various mulching materials did not significantly influence the length of bell pepper fruits in this study.

Additionally, the interaction between soil enhancers and mulching materials did not show a significant effect on fruit length. Statistical analysis confirmed that there were no significant differences in fruit length across the various treatments of soil enhancers and mulching materials during the off-season production of bell peppers. The length of bell pepper fruits, as influenced by soil enhancers and mulching materials, is detailed in Table 4.

Table 4.

Average length of fruits of bell pepper as influenced by soil enhancers and mulching materials

Soil Enhancers	**Mulching Materials**				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	3.95	4.23	3.82	4.14	4.03
Carabao manure	3.69	4.54	4.69	4.14	4.26
Goat manure	3.49	3.89	4.70	4.37	4.11
Chicken manure	4.54	3.73	4.55	4.55	4.34
Means	**3.92**	**4.10**	**4.44**	**4.30**	
CV (%)					**16.97**

Diameter of fruits

The study results revealed a significant difference in fruit diameter among various soil enhancers. The average fruit diameter ranged from 3.66 cm to 4.35 cm across the different treatments. The largest diameter was observed in plots treated with chicken manure, which had an average mean of 4.35 cm. This was followed by plots treated with goat manure, with a mean diameter of 3.83 cm, and plots treated with carabao manure, which had a mean diameter of 3.67 cm. These results are detailed in Table 5.

In contrast, the application of mulching materials did not significantly influence fruit diameter. Among the mulching materials, rice straw produced the widest fruit diameter, with an average mean of 4.08 cm. This was closely followed by plots treated with plastic mulch, which had a mean diameter of 4.05 cm. The untreated plots and those treated with rice hull recorded mean diameters of 3.72 cm and 3.64 cm, respectively.

The interaction between soil enhancers and mulching materials did not significantly affect fruit diameter. Statistical analysis confirmed that while chicken manure significantly increased fruit diameter compared to other soil enhancers, the application of different mulching materials and their interaction with soil enhancers did not produce significant differences in fruit diameter.

These findings suggest that chicken manure is particularly effective in enhancing the diameter of bell pepper fruits, likely due to its capacity to improve nutrient uptake and foster vigorous plant growth. The results on fruit diameter in this study are comparable to those of Borres et al. (2022), which ranged from 3.749 cm to 4.457 cm using rice straw as mulch under different photoperiods in the same soil type. This observation aligns with Khan et al. (2017), who noted the beneficial effects of chicken manure on plant growth. Similarly, Adhikari et al. (2016) reported that chicken manure has a more pronounced impact on vegetable growth, including fruit diameter, compared to other types of manure.

Table 5.

Average diameter of fruits of bell pepper as influenced by soil enhancers and mulching materials

Soil Enhancers	**Mulching Materials**				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	3.45	3.67	3.70	3.81	**3.66***b*
Carabao manure	3.39	3.59	3.98	3.70	**3.67***b*
Goat manure	3.74	3.60	4.20	3.76	**3.83***b*
Chicken manure	4.31	3.71	4.44	4.93	**4.35***a*
Means	**3.72**	**3.64**	**4.08**	**4.05**	
CV (%)					**14.84**

Level of significance: means with the same letter are not significantly different

Number of fruiting branches per plant at last harvesting

Table 6 presents the results on the number of fruiting branches influenced by the application of soil enhancers and mulching materials. The data reveal significant differences in the number of fruiting branches due to soil enhancer applications, with mean values ranging from 2.51 to 3.45 branches. Plots treated with chicken manure exhibited the highest number of branches, averaging 3.45, indicating a substantial increase in fruiting potential. This was followed by plots treated with goat manure, which had a mean of 2.88 branches, carabao manure with 2.57 branches, and untreated plots with the lowest mean of 2.51 branches.

The results of this study align with those of Borres et al. (2023), which found that the application of chicken dung tea in chili peppers resulted in a higher number of fruits and fruiting branches. These findings suggest that soil enhancers, particularly chicken manure, significantly improve the number of fruiting branches in bell pepper plants.

Similarly, the application of mulching materials also showed notable differences, with mean values ranging from 2.43 to 3.06 branches. Untreated plots and plots treated with goat manure exhibited the highest mean values, at 3.06 and 3.00 branches, respectively. This was followed by plots treated with plastic mulching, which had a mean of 2.43 branches. These findings indicate that while mulching materials have an impact on the number of fruiting branches, the effect is less pronounced compared to soil enhancers.

Statistical analysis confirms that there are significant differences among the treatments involving soil enhancers and mulching materials. Notably, plots treated with chicken manure consistently showed enhanced fruiting branches compared to other treatments. The interaction effects between soil enhancers and mulching materials also revealed significant differences, suggesting that the combined application of these factors influences the number of fruiting branches in bell pepper plants.

The superiority of chicken manure over other soil enhancers in promoting fruiting branches aligns with the findings of Adhikari et al. (2016), which highlighted the substantial impact of chicken manure on vegetable growth. Additionally, the nutrient content of poultry manure is generally higher compared to other types of animal manure (Borres et al., 2023). Chicken manure's nutrient-rich profile, including essential macro and micronutrients, enhances the plants' ability to absorb and utilize nutrients effectively. This results in vigorous growth and increased branch development, as supported by Khan et al. (2017).

Table 6.

Average number of fruiting branches in bell pepper as influenced by soil enhancers and mulching materials

Soil Enhancers	**Mulching Materials**				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	2.93b	2.53b	2.27c	2.33a	**2.51**
Carabao manure	2.27b	2.87ab	2.67bc	2.47a	**2.57**
Goat manure	2.67b	3.40a	3.27ab	2.20a	**2.88**
Chicken manure	4.40a	3.20ab	3.47a	2.73a	**3.45**
Means	**3.06**	**3.00**	**2.92**	**2.43**	
CV (%)					**16.58**

Rice straw, when used as a mulch, offers multiple benefits, including moisture conservation, soil temperature regulation, weed suppression, and gradual nutrient release through decomposition (Hung et al., 2020). The combination of rice straw and chicken manure can create a synergistic effect, enhancing soil structure, moisture retention, and nutrient availability, thereby improving plant growth and yield. The interaction between chicken manure and rice straw demonstrates that integrating these two treatments can lead to improved plant performance. The organic matter from rice straw enhances soil health and moisture-holding capacity, while chicken manure provides essential nutrients. This combination can result in increased growth, better nutrient uptake, and overall enhanced vegetable production (Samnoudi et al., 2019).

The application of chicken manure significantly increases the number of fruiting branches in bell pepper plants, while mulching materials, particularly rice straw, also play a role but with less impact. The combined use of chicken manure and rice straw can offer synergistic benefits, improving both soil health and plant growth.

Marketable Fruit

The marketable fruit yield per plot of bell peppers during off-season production, as presented in Table 7, reveals a range of yields from 0.23 to 0.27 kilograms across different soil enhancers. The highest yield was observed in plots treated with chicken manure, with an average of 0.27 kilograms. Plots treated with goat manure and untreated plots yielded 0.24 kilograms each, while plots treated with carabao manure recorded the lowest yield of 0.23 kilograms. For mulching materials, yields ranged from 0.22 to 0.26 kilograms per plot. The untreated plots had the lowest yield of 0.22 kilograms. Plots with rice hull and rice straw yielded similar amounts of 0.24 kilograms, while plots treated with plastic mulch had the highest yield at 0.26 kilograms.

The results indicated that neither soil enhancers nor mulching materials significantly affected the yield per plot of bell peppers. Additionally, no interaction effects between soil enhancers and mulching materials were observed.

Table 7.

Average marketable fruit yield per plot in bell pepper as influenced by soil enhancers and mulching materials

Soil Enhancers	Mulching Materials				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	0.20	0.25	0.22	0.28	**0.24**
Carabao manure	0.22	0.22	0.28	0.20	**0.23**
Goat manure	0.22	0.25	0.26	0.25	**0.24**
Chicken manure	0.24	0.23	0.30	0.33	**0.27**
Means	**0.22**	**0.24**	**0.26**	**0.26**	
CV (%)					**30.35**

The overall yield in this study was notably lower than the expected 4.5 kilograms per 4.4 m^2 plot size, as reported by Mariano and Jimenez (2021). This discrepancy can be attributed to adverse environmental conditions, including continuous rainfall during vegetative growth, drought during fruit development, and the presence of bacterial wilt and root rot disease, as detailed by Alhasnawi et al. (2020). Statistical analysis confirmed that neither soil enhancers nor mulching materials had a significant impact on bell pepper yield, and there were no significant interaction effects between these two factors.

Marketable Fruit

The study presents the marketable fruit yield of bell pepper per hectare, considering the application of soil enhancers and mulching materials. The data reveals that the application of soil enhancers resulted in mean values ranging from 528.61 to 615.52 kilograms per hectare. Table 8 showcases the marketable fruit yield of bell pepper per hectare in kilograms, influenced by these applications.

The highest yield per hectare, recorded at 615.52 kilograms, was observed in plots treated with chicken manure. Plots treated with goat manure had an average yield of 581.41 kilograms, while those treated with carabao manure recorded a mean yield of 555.72 kilograms. The untreated plots had the lowest yield at 528.61 kilograms. These results indicate that plots treated with different soil enhancers exhibited increased yields compared to untreated plots, although the yields were relatively similar among the different enhancers.

Regarding mulching materials, the plots treated with these materials recorded mean yields ranging from 501.74 to 634.75 kilograms per hectare. The highest yield of 634.75 kilograms was observed in plots treated with plastic mulching. Plots treated with rice straw had a mean yield of 605.08 kilograms, and those treated with rice hull had a mean yield of 539.70 kilograms. The untreated plots exhibited the lowest yield at 501.74 kilograms. Despite the application of plastic mulching showing the highest yield, the effect was not significantly different compared to other treatments.

Statistical analysis revealed that the soil enhancers, mulching materials, and their interaction effects showed no significant influences on the yield. This suggests that while soil enhancers and mulching materials can improve yields under certain conditions, their effectiveness can be diminished by adverse environmental factors.

In the first two months, the plants encountered unfavorable environmental conditions, characterized by continuous rainfall followed by drought conditions. The chosen sandy clay soil type exhibited high moisture content during rainy days and excessive compaction during drought, likely contributing to a decline in the off-season yield of the California Wonder variety of bell peppers compared to the anticipated yield of 10,000 kilograms per hectare (considered a good field yield according to Mariano & Jimenez, 2021).

It is important to note that actual yields can be influenced by various environmental factors, such as soil type, fertility, climate, irrigation, pest and disease management, and specific farming practices, as mentioned by Alhasnawi et al. (2020). A similar situation was observed in a study by Lee et al. (2018) on hot pepper, where abrupt changes and prolonged unfavorable weather conditions, such as high temperature, heavy rainfall, and drought due to climate change, were identified as main causes of a decline in pepper production. Excessive precipitation can saturate the rhizosphere with water, leading to anaerobic conditions that affect root penetration, growth, and photosynthetic activity. These conditions, along with physiological disturbances and abnormalities, can further impact yield (Lee et al., 2018). The off-season production of bell pepper was significantly affected by the aforementioned environmental stresses, even though the soil was treated with soil enhancers.

Table 8.

Average marketable fruit yield per hectare in bell pepper as influenced by soil enhancers and mulching materials(kg)

Soil Enhancers	Mulching Materials				
	Control	Rice hull	Rice straw	Plastic	Means
Control	454.24	564.39	503.78	592.02	**528.61**
Carabao manure	507.27	507.28	643.94	564.39	**555.72**
Goat manure	507.57	568.18	590.79	659.09	**581.41**
Chicken manure	537.87	518.93	681.81	723.48	**615.52**
Means	**501.74**	**539.70**	**605.08**	**634.75**	
CV (%)					**26.32**

Non-marketable fruit yield per plot in kilograms

The results of the study on non-marketable yield recorded mean values ranging from 0.015 to 0.018 kilograms per hectare. Among the soil enhancers, plots treated with chicken manure had the lowest yield of non-marketable fruit, with a mean of 0.015 kilograms. This was followed by plots treated with goat manure, which had a mean of 0.017 kilograms, and then by plots treated with carabao manure and the control plots, both recording a mean of 0.018 kilograms. Table 9 presents the non-marketable fruit yield of bell pepper per hectare influenced by the application of soil enhancers and mulching materials.

The results indicated that the application of soil enhancers did not significantly influence the yield of non-marketable fruit. The data suggest that despite the different treatments, the yields of non-marketable fruit were similar across all plots.

Regarding mulching materials, the non-marketable fruit yield ranged from 0.016 to 0.018 kilograms per hectare. Untreated plots and plots treated with rice straw had the lowest yield of non-marketable fruit, each with a mean of 0.016 kilograms. Plots with plastic mulching followed with a mean of 0.017 kilograms, and the highest mean was recorded by plots treated with rice hull at 0.018 kilograms. These results imply that the application of mulching materials did not show a significant difference in non-marketable fruit yield compared to the control.

Additionally, when considering the combined application of soil enhancers and mulching materials, there was no observed direct influence on the non-marketable fruit yield of bell pepper. Statistical analysis of the results showed that all treatment means were similar to each other, indicating no significant differences among the treatments. This suggests that the use of soil enhancers and mulching materials did not significantly affect the production of non-marketable fruit yield.

Table 9.

Average non-marketable fruit yield per plot of bell pepper as influenced by soil enhancers and mulching materials (kg)

Soil Enhancers	Mulching Materials				
	Control	Rice hull	Rice straw	Plastic	Means
Control	0.020	0.020	0.017	0.015	**0.018**
Carabao manure	0.019	0.020	0.016	0.019	**0.018**
Goat manure	0.014	0.019	0.017	0.020	**0.017**
Chicken manure	0.014	0.014	0.016	0.017	**0.015**
Means	**0.016**	**0.018**	**0.016**	**0.017**	
CV (%)					**19.31**

Non-marketable fruit yield per hectare in kilograms

The results of study on the non-marketable yield per hectare of bell peppers treated with different soil enhancers revealed means ranging from 34.65 to 41.48 kilograms. Among the soil enhancers, plots treated with chicken manure had the lowest yield of non-marketable fruit at 34.65 kilograms. This was followed by plots treated with goat manure, which had a mean of 40.14 kilograms, and untreated plots, which had a mean of 41.48 kilograms. Plots treated with carabao manure had a slightly higher yield. Table 10 presents the non-marketable fruit yield of bell pepper per hectare for each treatment. The results showed that the application of soil enhancers did not significantly influence the non-marketable yield of bell peppers. Despite slight variations in the means, the differences were not statistically significant.

Regarding the application of mulching materials, the yields of non-marketable fruit ranged from 37.88 to 42.23 kilograms per hectare. Plots treated with rice straw recorded the minimum yield of 37.88 kilograms, followed by untreated plots with a mean of 38.06 kilograms. Plots treated with plastic mulching had a mean yield of 40.71 kilograms, and those treated with rice hull recorded the highest yield at 42.23 kilograms. Despite these variations, the application of mulching materials did not result in a significant difference in non-marketable fruit yield.

The overall analysis of results revealed that neither soil enhancers nor mulching materials, whether applied individually or in combination, significantly influenced the non-marketable fruit yield of bell peppers. The statistical analysis confirmed that the treatment means were not significantly different from each other, indicating that these factors did not have a substantial impact on the production of non-marketable fruit.

Table 10.

Average non-marketable fruit yield per hectare of bell pepper as influenced by soil enhancers and mulching materials(kg)

Soil Enhancers	Mulching Materials				
	Control	**Rice hull**	**Rice straw**	**Plastic**	**Means**
Control	45.45	46.97	39.39	34.09	**41.48**
Carabao manure	42.42	46.97	37.12	43.94	**42.61**
Goat manure	32.57	42.42	39.39	46.21	**40.14**
Chicken manure	31.81	32.57	35.60	38.63	**34.65**
Means	**38.06**	**42.23**	**37.88**	**40.71**	
CV (%)					**19.31**

Conclusions

The findings of study revealed that the application of chicken manure reduced the number of days to flowering and increased fruit size. However, neither soil enhancers nor mulching materials significantly influenced the yield per hectare. While chicken manure improved certain growth parameters, the overall yield during off-season production remained unaffected by the treatments. Based on these findings, it is recommended to use chicken manure to enhance growth parameters such as flowering time and fruit size in off-season bell pepper production. To increase overall yield, further research should investigate additional factors such as irrigation practices, pest management, and other organic or inorganic soil amendments. Additionally, examining the combined effects of these treatments under different environmental conditions could provide more comprehensive insights into optimizing off-season bell pepper production.

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